IRON and STEEL
ENGINEER

J. F. KELLY, Editor

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MEETINGS AND PAPERS

PHILADELPHIA SECTION

P. T. Vanderwaart, Chairman **L. O. Morrow, Secretary**

Saturday, March 7th, 1925

"Foreign Steel Mill Practice." A Committee Report. Members of Committee: Walter H. Burr, Chairman, Elec. Supt., Lukens Steel Company, Coatesville, Pa.; F. B. Crosby, Engr., Morgan Construction Company., Worcester, Mass.; F. L. Estep, Perin & Marshall, Consulting Engineers, New York, N. Y.; O. Needham, General Egineering Department, Westinghouse Elec. & Mfg. Company, East Pittsburgh, Pa.; B. R. Shover, Consulting Engineer, Pittsburgh, Pa.; L. A. Umansky, Engr., Industrial Dept., Steel Mill Section, General Electric Company, Schenectady, N. Y.

Engineers Club **Philadelphia, Pa.**

CHICAGO SECTION

R. L. McIntosh, Chairman **W. H. Williams, Secretary**

Thursday, February 26th, 1925

"Can the Synchronous Motor be successfully applied to Steel Mill Main Drives."

Atlantic Hotel **Chicago, Ill.**

CLEVELAND SECTION

R. E. Scoval, Chairman **A. R. Lintern, Secretary.**

Monday, March 9th, 1925

"Methods Employed in the Manufacture of Steel Cables," by C. C. Sunderland, Chief Engr., John A. Roebling's Sons Co., Trenton, N. J.

PITTSBURGH SECTION

R. E. Lewis, Chairman **John F. Kelly, Secretary**

Saturday, February 21st, 1925

"A Discussion of Present Day Wire Rope Problems," by James F. Howe, Wire Rope Engineer, American Steel & Wire Company, Worcester, Mass.

BIRMINGHAM SECTION

F. G. Cutler, Chairman **W. W. Garrett, Secretary**

W. H. Dunn **Executive Committee** **W. H. Gilbert**

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EDITORIAL

THE IRON AND STEEL ENGINEER

The Iron and Steel Engineer, the leading engineering periodical of the Steel Industry, enters its second year with the hope that it may be able to render a still greater service to the engineers in the industry, by keeping them informed of the latest developments in the electrical, mechanical and combustion arts.

Most of the improvements in the steel industry this year will consist of the rehabilitation of the existing plants and the installation of additional finishing plants. Naturally, there will be a demand for data covering the equipment of the present modern plants and two of the frequent questions will be:

How many BTU's per ton

How many KWHrs per ton

Our editorial staff, the electrical and combustion divisions of the A.I.&S.E.E. will answer these questions and many others during the year.

All of the papers presented before the district sections of the A.I.&S.E.E., the proceedings of the Combustion Engineering Division, the convention transaction, will appear in the Iron and Steel Engineer.

The Safety Section of the A.I.&S.E.E. will also be given a prominent section.

ELECTRICALLY HEATED SOAKING PITS

Like every other new innovation, the Electrically Heated Soaking Pit, must prove its superiority in every particular, before its universal adoption.. It has its merits beyond any doubt, however; it has still some disadvantages, and all of the disadvantages must be overcome before the gas-fired pit is eliminated.

In this issue is contained a paper covering the performance of an electrically-heated soaking pit, operating at the Donner Steel Company, at Buffalo, N. Y.

We believe this paper is the first one ever presented covering the operation of an Electrically-Heated Soaking Pit.

The complete discussion on this paper will appear in the March issue of Iron and Steel Engineer.

FUEL SAVINGS CONFERENCE

At the last committee meeting of the Combustion Engineering Section of the A.I.&S.E.E., it was decided to hold the Annual Fuel Savings Conference at Pittsburgh on May 13th and 14th, 1925.

A power show will be held in connection with the conference, and all of the manufacturers of Power Apparatus will be given an opportunity to display their apparatus.

Details in connection with the papers and show will be printed in the next issue of this periodical.

ANNUAL CONVENTION AND IRON AND STEEL EXPOSITION

At the last regular meeting of the Board of Directors it was decided to hold the Annual Convention and Iron and Steel Exposition in the City. of Philadelphia during the week of September 14th to 19th, 1925.

The technical sessions will cover the subjects of Safety, High Tension Switching, Motors, Combustion, Electric Heating, Power House Auxiliaries, etc.

The Iron and Steel Exposition will, in all probability, be held in the Philadelphia Commercial Museum, one of the largest auditoriums in the United States. Over 100,000 square feet of space will be available for exhibits.... This will be the largest exposition in the history of the A.I.&S.E.E.

In order that you may keep fully informed of the details and happenings of the Convention and Exposition, we will print some worth-while information in every issue of the Iron and Steel Engineer.

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Auxiliary Motor Control

By W. W. GARRETT*

THE selection of a proper control for auxiliary units in the steel mill is a point that must be given careful consideration. In some of our old mills a control scheme that would start, stop and reverse the auxiliary equipment at a speed fast enough to keep the mill in operation was about all that was desired. But in our more modern mills, where electrification of mill drive has become practically universal and where a large portion of the money invested is in electrical equipment, the question of protective control devices has become very essential.

The object of this paper is to consider the proper adjustment most suitable to the particular requirements of individual mill auxiliaries. This discussion of auxiliary control will refer primarily to the controls for Manipulating or Intermittent Drives, which service is now universally performed by direct current motors.

To meet the requirements of the modern steel mill, various schemes of magnetic control have been designed and installed. The requirements are:

First: It must not interrupt the operation of the mill, but must on the other hand, increase the output.

Second: But by no means less important, it must serve as a protection against the severe duty common to all steel mill auxiliary drives.

Magnetic switches controlled by series relays with overload relay protection, operated by two speed mill type controllers, seems to be the most common control equipment for all secondary auxiliaries. A few examples of secondary auxiliaries are running drives where direct current motor acceleration and reversals do not have to take place in one second, as non-reversing tables, ingot buggies, ordinary crane service and continuous duty drives.

For primary auxiliary duty, such as reversing delivery tables, lifting rigs, ladle cranes and screw down drives, where acceleration or de-celeration must take place in one second or less it has been found from experience that magnetic control can not be successfully operated with series relays, because it takes too much time for these relays to operate before the contactor switches begin to close. It is then impossible to get the required number of switches to operate in so short a period as this type of drive calls for. It is an established fact that in a modern mill these accelerations and de-celerations must take place in one second or less, to properly serve the mill. A smaller resistor with a less number of switches would not have enough capacity to carry the current, as will be shown later. In operating such drives, the series relays are omitted. The time element of the switches and the number of switches then determines the acceleration period. The problem in the successful operation of this control is to limit the accelerating current peaks by properly adjusting the several resistance steps in the resistor. Since the number of switches fixes the time of acceleration it is a simple matter to increase or decrease this time by increasing or decreasing their number provided, of course, proportional adjustment can be made in the resistor.

*Engineer of Tests, Tenn. Coal, Iron & R. R. Co., Birmingham, Ala.

Figure 1 is a theoretical acceleration diagram suitable for showing the current action in any d-c motor when operated by magnetic switches with series relay control. The diagram is plotted for an acceleration period of one second or less, as this is the time usually allowed on primary operations. Two 100 H. P. series shunt motors in series are generally used on such drives in our Fairfield Mills and this diagram has been plotted to suit these particular conditions. I is the rated full load or 100% current and Imax is the necessary starting current generally taken as 150% rated full load current. One, 2 and 3 are the several magnetic contactors controlled by series relays. R1 to R3 are the several resistance steps denoting the percentage of resistance cut out as each successive contactor closes. Ra is the armature resistance taken as 20% of R for two motors in series and from 7% to 10% for single motors. The number of switches on each contactor board is always one less (n-1=2 in this case) than the number of peaks in the acceleration curve. Analyzing this curve, consider the motors as starting from rest, as shown at the lower right hand corner of the

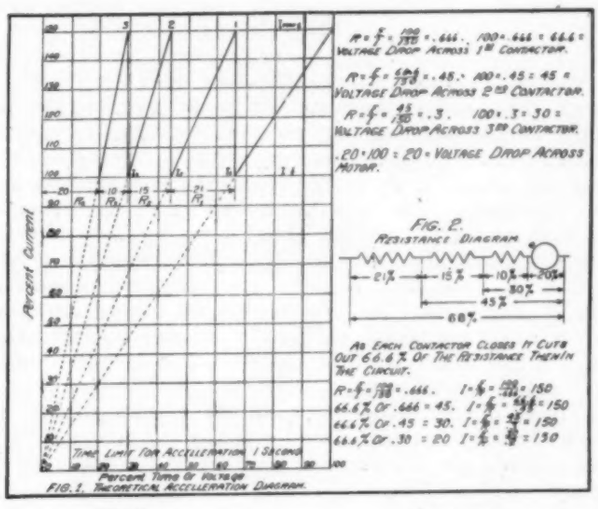

FIG. 1 FIG. 2

diagram. As the controller is thrown on the current passes through the overload relay. The main controller and reversing contactors all being simultaneously closed, the current passes through the entire resistance in series with the motor and rises to Imax. (150% motor current rating.) The motor begins to accelerate as the armature counter voltage builds up and the current falls from Imax. to I, at which point the first relay operates closing No. 1 contactor, jumping out resistance R1, the current again rising through the remaining resistance to Imax. As the motor continues to accelerate the current again falls to 1 and relay No. 2 operates closing No. 2 contactor which cuts out resistance step R2. The current peak again rises to Imax. and falls off as the motors accelerate. This procedure continues until all the resistance steps are cut out. Then the current peak in the last contactor falls to a point either the friction load or actual load of the motor. The diagram shows that 30% of the total acceleration time is left for the

motors to build up to full speed after the last contactor closes, 20% of this time being consumed in overcoming the armature resistance and 10% of this time is allowed to bring the motor up to full speed. The next step in developing the theoretical operation is to determine the exact amount of resistance that must be used in each step of the resistor to give the desired starting peaks. Figure No. 2 is a resistance diagram. Assuming the motor flux as constant, the total resistance R of the resistor and motor circuit is determined by the simple application of Ohm's law. The following steps of the resistor are so proportioned that the momentary rush of current, as each additional step of the resistor is introduced, will not exceed the required Imax. Referring to the first example in Fig. 2 the resistance and voltage drop across each contactor step is figured. In the second example in Fig. 2 another scheme of arriving at the proportions of these resistor steps is shown.

Referring to Fig. 3, an actual acceleration curve is shown, taken from two 100 H. P. series shunt motors

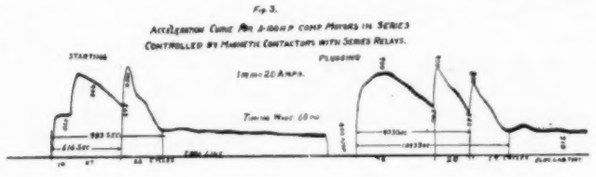

FIG 3

connected in series, driving the rolls of a reversing delivery table in the Blooming Mill at the Fairfield Works. Only two of the five regular contactors on this control panel were used, the remaining switches being cut out for this test. The two contactor switches being operated by continuous duty coils through series relays. Previous to making the picture the grids in the resistor were arranged according to the theoretical examples given above. As the time of this acceleration was limited to one second it was not possible to use more than three switches as explained in Fig. 1. It will be noted that a theoretical acceleration curve is not obtained when the motor starts from rest. As the most severe service of these motors is on plugging, the resistor was so arranged and the relays so adjusted as to give as nearly as possible the theoretical curve under the most severe duty.

Examining the curve in Fig. 3, it will be seen that the first peak in starting rises to 470 amperes, the sec-

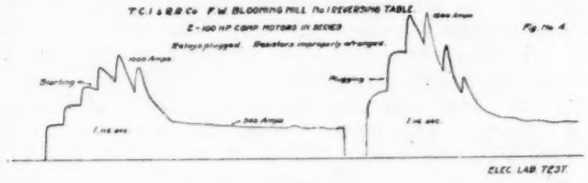

FIG. 4

ond peak to 930 amperes and the third to 1,000 amperes. The actual time taken for the two switches to operate is .616 second and the motors were under full speed from rest in .983 sec. drawing 310 amperes under friction load. On plugging the first peak rises to 900 amperes, the second to 930 amperes and the third to 800 amperes, running again under friction load at 310 amperes. The time for the two switches to operate was .933 sec. and the motor was under full load speed from plugging in 1,293 sec. It is noted that the series relays operated in each case around 540 amperes, also that the plugging peaks are not any higher than the starting from rest current peaks. It would have been possible to have used three accelerating switches in starting from rest, but on plugging the time limit of one second is reached with two switches. If another switch was introduced the starting peaks could be lowered but the time required would not be in the one second limit. From further tests it was shown to be impossible to operate the contactors faster than .16 sec. per switch, if the series relays were used. Also that it required .2 sec. for the series relay to

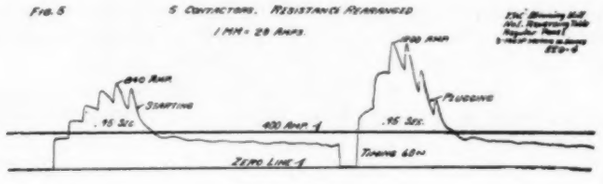

FIG. 5

operate before the switch begins to close. Hence it would be impossible to use more than two relay operated switches and still come within the time limit. Referring to Fig. 1, it will be seen that the area of an accelerating triangle is always constant, no matter what the starting conditions might be. If the time element of the switch is shortened the current peaks will be higher and vice versa. With the motors operating under these conditions the time of acceleration is accomplished, but the current peaks did not bring the motors up to operating speed, consequently the resistor was continually carrying these peaks which ran the grids red hot in two hours' operation. It was evident that the time for operation of the switches had to be greatly decreased and that more resistance units would be necessary to split up the accelerating current. By plugging out the series relays it was possible to reduce the time of operation of the contactors to .16 sec. which is the time element of the switch alone. Further tests showed that the motors would actually accelerate to a sufficient speed to operate the rolls in less time than the five regular switches on this control could be automatically closed. Therefore the protection to the motors still remains, after the series relays are cut out and the time element of the proper number of switches is the limiting protection. The two overload relays,

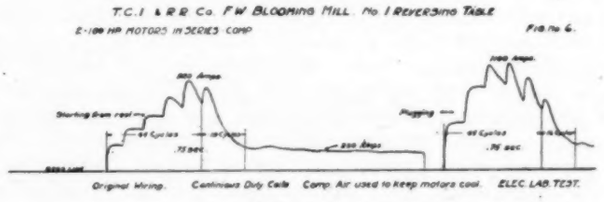

FIG. 6

one on each side of the line, being a double protection in the extreme cases. Now five contactors will close in .8 sec. or .16 sec. per switch. After further research we found that the speed of the contactors themselves could be reduced from .16 sec. to .12 sec. by operating them with mill duty coils instead of continuous duty coils. The mill duty coils have about ¼ less turns, build up in .04 sec. less time than the former coil and serves intermittent operation successfully.

Previous to this oscillograph investigation, the gear ratio on the reversing roll drives had been increased from 2 to 1, to 6 to 1; as it was found that the excessive current peaks were burning up the resistors and it was necessary to keep cooling air on the motors to operate them at all. A paper read by Mr. J. E. Fries of this Association on "Influence of Gear Ratio on Speed of Operation," gives in detail the particulars of this trouble and the success obtained by increasing the

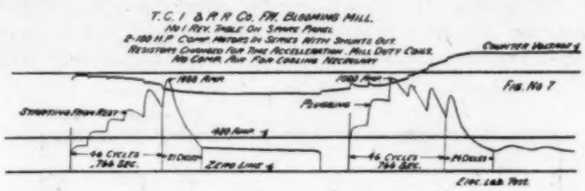

FIG. 7

gear ratio. With the gear ratio trouble out of the way it was possible to begin a series of tests to properly adjust the resistors.

The object of the oscillograph investigation was to determine the present condition of the control panels and to find what changes could be made that would give the desired acceleration of the motors and bring the operation of the mill up to a maximum. The first control to be investigated was one operating a reversing delivery drive. With all the relays functioning on this drive, the time of acceleration from stand still was 1.6 sec. and on plugging 2.6 sec. This, of course, was entirely too slow for mill operations. Fig. 4 is an oscillograph picture showing the actual acceleration curve of two 100 H. P. series shunt motors referred to above, on a reversing delivery drive. As found when our investigation began, all five switches were working, but all five relays had been blocked out in order to give as nearly as possible the time limit of one second acceleration and to keep the mill in operation. The curve shows that the actual time taken to accelerate from rest and plugging required 1.166 sec. The starting from rest peak reached nearly 1,000 amperes and the plugging peak nearly 1,500 amperes. The rated current being 400 amperes for each of the two motors in series. It is obvious that these peaks are entirely too high and the time of acceleration of the switches is above one second. Upon investigation we found

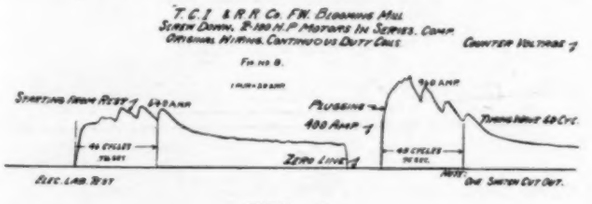

FIG. 8

that the arrangement of resistor units had been changed. Where there was formally one bank, there were now two banks in multiple in order to give ample capacity for carrying the enormous current peaks drawn by the motors before the gear ratio had been increased. After the gear ratio adjustment naturally these resistance units were taking more than enough current to handle the load. The resistor was then rearranged and Fig. 5 shows an unsuccessful effort to adjust this control. Here the acceleration from rest and plugging takes place in .95 sec. The current peak on starting is now 840 amperes and the plugging peak is 1,200 amperes. The current peak on plugging is still a little too high. The grids of the resistor were then rearranged according to factory drawings. Fig. 6 shows the resistor operating with continuous duty coils and all relays plugged. The switches now close in .75 sec. and the starting current peak rises to 920 amperes and on plugging, to 1,100 amperes. We then substituted the mill duty coils to speed up the action of the

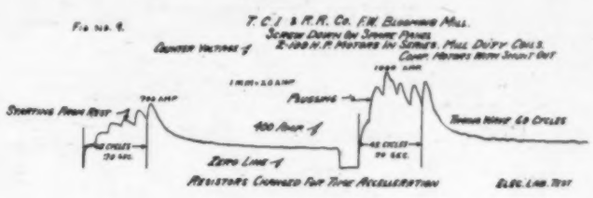

FIG. 9

switches. Fig. No. 7 shows the final outcome of the results obtained which were satisfactory. The curve now shows that the acceleration from rest and plugging occurs in .766 sec. This is a fraction slower than in Fig. No. 6, but the real advantage gained is that the current taken in both starting and plugging instances, is 1,000 amperes. It is of interest to note that now the more severe service on plugging does not require any more current than the starting from rest duty. Also that we have reduced the time of acceleration of the switches from 1.166 sec. to .766 sec. or a gain of 34% in time from what it was when we first began our observations in Fig. No. 4. The controllers all operate nicely under these conditions and no more cooling air is necessary to keep the motors operating. Examination of the motors showed that commutation was perfect.

A counter voltage curve is shown on Fig. No. 7, indicating the rise of potential as each successive step of the resistance was cut out. Examining the plugging curve it will be seen that three contactors have actually closed before the motor is de-celerated and begins to rotate in the opposite direction as is shown where the curve crosses the zero line and takes up a new position. The time involved in this de-celeration is .5 sec. These motors have now been in service for six months since the gear ratio and resistor adjustments were made. From all indications we may expect an extended dura-

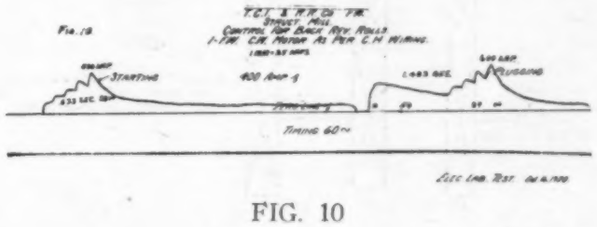

FIG. 10

tion of the life of this drive. Repairs and replacements on the contactors have also been reduced to a minimum.

The next control to be adjusted was on the screw down drive at the same Blooming Mill. Previous to these tests the gear ratio had been increased from 2 to 1 to 3 to 1 as explained in Mr. Fries' paper previously referred to. The first step in this adjustment was to see that the boards were arranged according to specifications; and that the series relays were all plugged out. Fig. No. 8 shows that the time of acceleration

was .766 sec. from rest and .75 sec. on plugging. The highest starting current peak is 640 amperes and the highest plugging peak is 960 amperes. Note the improper performance of the curve on the first two switches. It appears as if the main contactor and the first and second switches might have been very nearly operating in conjunction. Fig. No. 9, shows these same motors after the contactor switches had been equipped

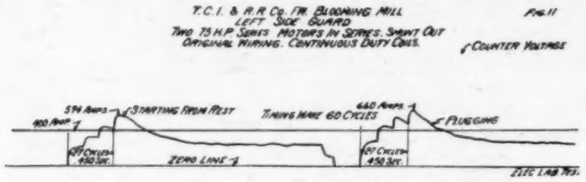

FIG. 11

with mill duty coils. Now all five switches are operating properly on both starting and plugging in .7 sec. The current peak on starting is 700 amperes and on plugging is 1,080 amperes. As plugging on a screw down drive is naturally the most severe service as compared to starting this curve is satisfactory; especially in view of the fact that the time of acceleration has been reduced by .06 sec., and the operation is now serv-

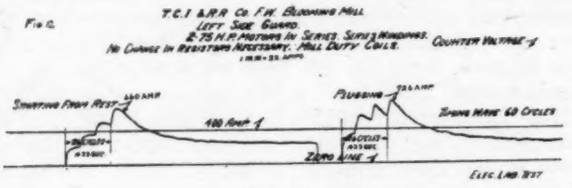

FIG. 12

ing the mill perfectly. There is now no further occasion for the use of cooling air on the motors, which have been in operation for one year and are still running nicely.

It will be noted in the above curves that the current readings have been taken at the highest peaks. In reality the general average of the area of each acceleration curve is the true burden of the motors. Such an average taken from the screw down curve in Fig. No.

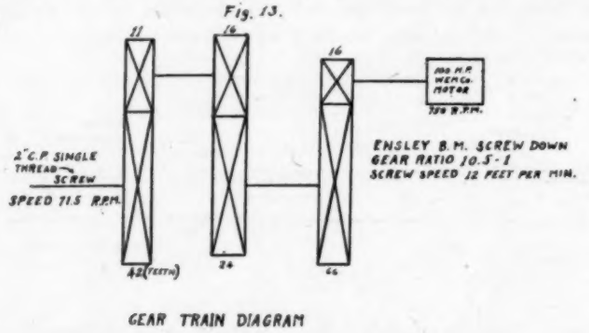

FIG. 13

8, shows that the burden on starting from rest and under load is approximately 500 amperes. On plugging and under load it is approximately 800 amperes. The fact is that in actual mill operation of such primary auxiliaries, the true intermittent load of the motors is always the average of the acceleration current curve. It can not be less because the reversals of the mill take place so rapidly that the current does not appreciably fall to the normal rating of the motors. It is then obvious that a control of sufficient capacity be installed, that will not only break the arcs of the accelerating current peaks but at the same time handle the load current of the motors in average mill operation.

Fig. No. 10 shows a control in the Plate Mill operating the back reversing tables, where the relays were all supposed to be blocked out. It is shown from the curve that the relay on the first switch worked when the motor was reversed taking .833 sec. to operate. To adjust this control we simply made sure that

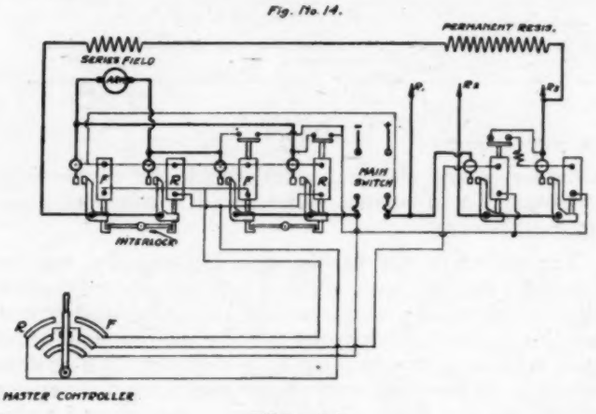

FIG. 14

the relay was positively blocked; thus speeding up this drive .833 sec. on each plugging operation of the motor.

The curve in Fig. No. 11 is taken from a control with the original continuous duty coils on the contactors. Acceleration and de-celeration of the motors operated by this control takes place in .45 sec. Special mention is here made to the accuracy of the oscillograph in detecting the most minute details of this control. An irregularity is seen at the point of the curve just before the motor was shut down, from its starting from rest run. Here the operator was a little slow in bringing the lever of the controller all the way back to neutral position, and the motors for an instant (actually .1 sec.) ran on the first controller point. Fig. No. 12, shows a curve taken from this same control after mill

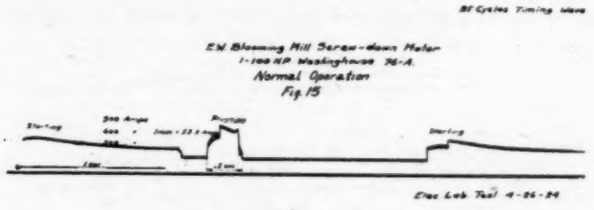

FIG. 15

duty coils had been substituted for the original continuous duty coils. The acceleration and de-celeration periods are now .433 sec. or just .072 sec. faster than in the former case.

For further discussion along the line of control, some very interesting tests and data have been collected from the 44-inch Bloommon Mill Screw Down at the Ensley Works. This drive was first installed in 1908 and the Electrical Superintendents have succeeded in building for themselves a scheme of control that is in many respect very unique in its designs and highly effective in its results. In this mill the screw down

service is performed by a 100 H. P. 750 R. P. M. series motor, through gear trains of a 10.5 to 1 ratio Fig. 13 is a schematic diagram showing the arrangement of this drive. The control switches are of the contactor type. The two forward and the two reversing switches are of 600 ampere capacity, and the two accelerating switches are of a 400 ampere rating. There is inserted in the line to the field circuit a permanent limiting resistor, which prevents the current from rising above a predetermined point (150% full load current rating) under any conditions of operation. This control is operated from a two point forward,

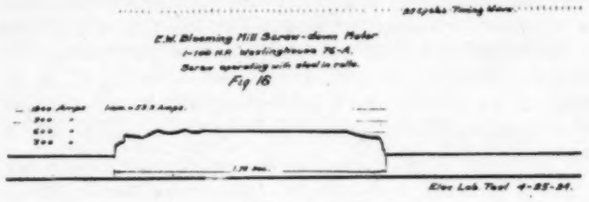
E.W. Blooming Mill Screw-down Motor
1-100 H.P. Westinghouse 76-A.
Screw operating with steel in rolls.
Fig. 16
Elec. Lab. Test 4-25-24.

FIG. 16

two point reverse master drum. See Fig. 14. On the first point of the controller the entire resistance is thrown into the circuit, see diagram R1-R2, R2-R3 in figure 14. As the accelerating switches operate the starting resistance is cut out, leaving the resistance of the motor together with the resistance of the limiting resistor in the circuit. With this arrangement neither the motor nor the control can be excessively overloaded under any conditions of operation. The accelerating switches being only two in number always insures quick starting. Quick stopping is also as easily obtained. There are no brakes either mechanical or electrical on this drive, braking being performed only through the resistor. When the operator throws the controller on the first point the motor is started through the entire resistance. On the running point the current flow is limited by the permanent resistor in the motor circuit. In the event the motor is plugged straight across the line, the limiting resistor will prevent an excessive current peak.

Fig. 15 is an oscillogram showing the normal operation of this control. It will be noted that on starting the current does not rise above 450 Amps. On plug-

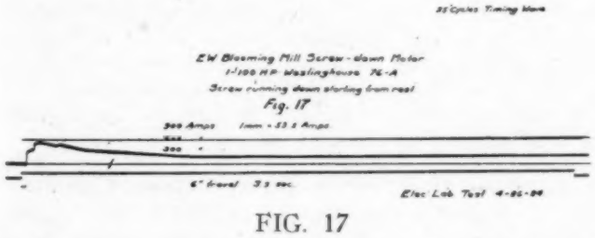
E.W. Blooming Mill Screw-down Motor
1-100 H.P. Westinghouse 76-A
Screw running down starting from rest
Fig. 17
Elec. Lab. Test 4-25-24

FIG. 17

ging straight across the line the current peak does not rise above 850 Amps. Acceleration is performed in one second, while the time required to actually plug the motor is .2 second.

Figure No. 16 is another oscillogram taken when the rolls were being driven down at the same time steel was passing through them. This kind of operation is common practice with all steel mill rollers, and due consideration was made of this fact in the assembling of the contactors, so as to make ample provision for this kind of duty. On examining the curve in this Fig. 16, it will be seen that the current did not exceed 650 amperes throughout the entire time of 1.72 seconds that the rolls were being forced down on the steel.

Figure 17, is an oscillograph curve taken to show the actual operating speed of the screw when started from rest and driven down for a 6-inch travel. The time required being 3.9 seconds. Starting from rest the rolls were raised 6 inches in 3.25 seconds as shown in

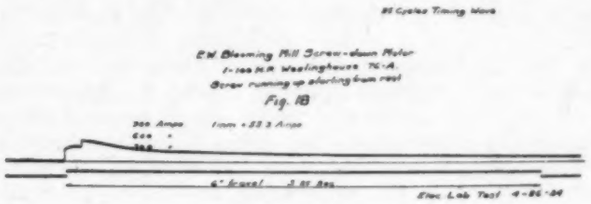
E.W. Blooming Mill Screw-down Motor
1-100 H.P. Westinghouse 76-A.
Screw running up starting from rest
Fig. 18
Elec. Lab. Test 4-25-24

FIG. 18

Fig. 18. With the screw traveling down at full speed after the motor had been accelerated, it was noted that a 6-inch travel was made in 2.1 sec. as shown in figure 19. With the screw running up at full speed under the same conditions, the time required to travel 6 inches was 1.7 seconds as shown in Fig. 20.

This mill has an average record of 35,24"x24" ingots per hour. On a special one hour test 46,24"x24" ingots were rolled.

On secondary Auxiliaries or continuous duty drives, the matter of prolonging the life of motors is easily accomplished where magnetic control is used. Here

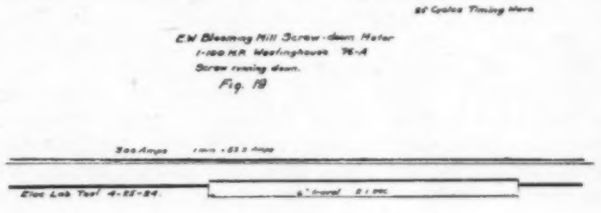

FIG. 19

the accelerating burden of the motors can be decreased by adjusting the series relay control so as to prolong the duration of the starting period to two, three or even more seconds, thus cutting the starting current peaks to the very lowest figure. On this class of drives where the time required to start motors does not affect mill operation, this point should be taken advantage of. If the relays are set to require about three seconds for the motors to come to speed, ample protection will be obtained. Of course each individual drive should finally be adjusted to suit its particular conditions. Thus the

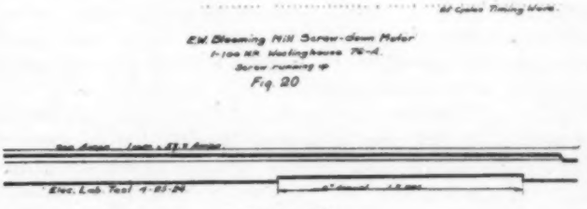

FIG. 20

proper adjustment of auxiliary motor control where each class of drives has its special requirements satisfied, has been the means of speeding up the production of our mill, of increasing the efficiency of our motors and of greatly extending the lives of these motors and their respective controls.

The Measurement of Electricity as Applied to Industrial Plants

By H. P. PRATT*

ALL industrial plants, regardless of whether they purchase power from a public utility or generate their own power, should be vitally interested in the methods used to measure this power and they should make systematic tests of their power consuming devices to determine whether or not these devices are working at their maximum efficiency. The types of measuring devices used to determine the power consumed depends, to a great extent, upon the class of load being measured and whether or not the supply is direct or alternating current. For this reason it seems advisable to give a brief description of the various types of instruments that may be used to measure the various loads.

In any electrical circuit to which a load is connected, we have available a pressure or voltage, and a current flow; the pressure in general being constant and the current varying with the applied load. The power or rate of expenditure of electrical energy in a circuit in any instant is, in the case of direct current circuits, always equal to the product of the current flowing at that instant, measured in amperes, and the voltage at the terminals of the circuit at that instant. In other words, power in watts is equal to the product of the amperes and volts flowing at any given instant in a direct current circuit. The power in an alternating current circuit involves an additional factor which is taken up later in this paper, but it also requires the measurement of volts, amperes and watts. Hence, we are most concerned with the operation of ammeters, volt meters and watt meters.

There are three groups into which these instruments may be divided and for convenience these are called indicating, integrating and graphic meters. An indicating meter is one in which a pointer moves over a scale and indicates at any instant the value of the quantity being measured by the instrument. A graphic instrument is similar in a great many respects to the indicating instruments but, in place of a fixed scale, the instrument is provided with a chart which moves under a pointer and as the pointer carries a stylus or pen, the chart gives a record of the position of the pointer at any given instant. The chart in this type of instrument is moved by a clock and the rate of movement can be varied to suit the conditions of the test. In general both of the groups show instantaneous values. However, in the case of the graphic it is possible to determine the actual time interval during which certain quantities were measured.

The integrating instrument differs from either of the above in that the factor of time is involved when measurements are taken with them. In other words, these meters register the electrical quantity measured over a period of time and in no case do they give from observation the instantaneous value of the quantities under measurement.

Both the indicating and the graphic ammeters and volt meters are essentially alike in their general construction. Ammeters and voltmeters consist of a fixed and moving coil, a pointer attached to the moving coil and a fixed scale over which the pointer moves. Ammeters are always connected in series with a circuit in which measurements are being taken, that is, they are connected in such a way that the total current passes through the instrument. Voltmeters on the other hand are connected across a circuit to be measured and indicate the difference in pressure of the circuit. With the exception of ampere hour meters which have a limited application, ammeter and voltmeters are not used as integrating devices.

As a general proposition, power measurements as such, are usually taken with watt meters and energy measurements which require a time interval are taken with watt-hour meters. The watt meter is similar in its constructional details to the ammeter and voltmeter in that it has a fixed and moving coil, a pointer attached to the moving coil and a fixed scale over which the pointer moves. It differs from the ammeter and voltmeter in that its fixed coil is connected in series with the circuit to measure the current consumed and its moving coil is connected across the circuit to be measured, hence the indications are the product of the current and voltage or watts. The watthour meter differs greatly in this construction from any of the classes previously discussed. The direct current watthour meter is in effect a small motor and it consists of a fixed coil connected in series with a circuit and a movable coil which is connected across th circuit; this movable coil being free to rotate. The current is led into and out of the movable coil by means of a commutator and brushes. The revolutions of this coil are transmitted through gearing to a register, which register is marked to indicate killowatt hours. The alternating current watthour meter differs again from the direct current watthour meter and this watthour meter has a current coil and a potential coil and these coils are wound upon laminated iron frames. Between these coils is placed a disc which is free to rotate and the speed at which the disc rotates depends upon the power in the circuit. The rotation of this disc is transmitted through suitable gearing to the register which is marked in kilowatt hours.

Measurement of Power in Direct Current Circuits

As a general proposition the measurement of power in direct current circuit is comparatively simple, as in this type of circuit the current flows out one wire and returns on the other wire of a two-wire circuit and the direction of current is always the same. The power flowing in this circuit can be measured by an ammeter and a volt meter of the indicating type and the sum of the readings obtained from the two instruments is a measure of the instantaneous watts or power flowing through the circuit at that instant. If it is desired to know the average watts taken by a load for a given period such as one hour, one day, etc., this method is not satisfactory, as it would require the continuous observation and recording of the readings of these two instruments for the period desired. A better method of measuring this power for a long period is to use the direct current

*Supervisor of Meters and Underground Department, Metropolitan Edison Co., Reading, Pa.

watthour meter, which meter will register on the dial the product of the average watts and of the time interval during which the power is being measured. It is, of course, possible to measure this power with graphic instruments, but one objection to this is that for long periods the charts must be minutely analyzed and observations for small increments of time must be calculated from the chart readings and then totalled to obtain the average power.

It has often been asked and justly so, why so many utilities are changing from direct current distribution to alternating current distribution. One of the factors, and by no means a small one, is the fact that due to the oxidization of the brushes and commutator on direct current watthour meters, it is extremely difficult to keep the watthour meter in adjustment so that it will measure the true power consumed; the general tendency is for these meters to run slow.

Measurement of Power in Alternating Current Circuits

The measurement of power in alternating current circuits is not as simple as the measurement of direct current circuits, and we will now consider some of the factors entering into this.

An alternating current circuit differs from a direct current in that the current no longer flows continuously out one wire and returns on the other wire. In a single-phase alternating current circuit the current and voltage start from zero, rise to a maximum value, return to zero, reverse and rise to a maximum value in the opposite direction and again return to zero. This change in the direction of flow is called a cycle and in a 60 cycle system we have 60 such reversals per second; thus in an alternating current system the terminals of the circuit are alternatingly positive or negative and the current flows first in one direction and then in an opposite direction. If in a given circuit the current keeps step with the voltage as it changes direction, the power can be measured with a voltmeter and ammeter and the power is volts times amperes, the same as in a direct current circuit.

Nearly all circuits, however, contain at some point, coils or turns surrounding or surrounded by iron and the frequent charging and discharging of these electromagnets by the reversals of the current, causes the current to get out of step with, or as we say, to lag behind the voltage; so that to give the same power as when they are in step, an increased current is required and the more they are out of step, the greater this increase in current. A magnetic field absorbs energy when the current is increasing and is building up the field and it returns energy when the current is decreasing and the magnetic field is dying away, in the same manner that a spring does when subjected to a varying pressure.

In any single-phase circuit containing a magnetic field the pointers of an ammeter and a voltmeter will indicate the effective values of the current and voltage that exist in the circuit, but as the current is lagging or out of step with the voltage, the average power of this circuit will be less than the product of the volts-amperes and the ammeter-volt meter product is called the apparent power to distinguish it from the real power and the unit of the apparent power is the volt-ampere. When the current and voltage reach their maximum values at different times, we say that the current is out of phase from the voltage, or that there is a difference in phase between the current and voltage. It is possible by means of specially designed instruments such as an oscillograph, to obtain a picture of the voltage wave and the current wave and to determine from this picture the actual angle by which the current lags behind the voltage; this angle being called the *phase angle.*

We now have a circuit in which the current is lagging behind the voltage and we wish to determine the apparent power and the real power of the circuit. As previously stated, the apparent power can be obtained with an ammeter and a volt meter, but the real power must be obtained with a watt meter. As the current in the current coil of the watt meter and the voltage in the voltage coil of the watt meter are reaching their maximum values at different times, the watt meter will actually indicate only the real power in watts which is being consumed by the load. As the watts will be less than the volt amperes for a given condition of load, there will be a certain relation between the apparent power (volt amperes) and the true power (watts), and this relation or difference is called the power factor and is obtained by dividing the watts by the volt amperes. When the current and voltage are in step, we say that the power factor is unity, or in other words, the volt-amperes and watts are equal. When the watts are less than the volt amperes the power factor is less than unity and its value depends upon the particular load connected.

Practically all power is supplied from a poly-phase circuit. A poly-phase circuit consists of two or more single phase alternating current circuits in which the respective voltages are out of phase and this phase difference depends upon the particular system used. In a two-phase system the voltage between phases is 90 degrees, while in a three-phase system the voltages differ in phase by 60 degrees or 120 degrees. As previously stated, the power in watts in a single phase circuit may be measured with a watt meter. In a three-phase circuit, the power is usually measured by either two single phase watt meters, or these two watt meters may be combined constituting a poly-phase watt meter, in which case the movable coils are mounted on the same pointer shaft.

It is advisable to consider the question of power factor and its measurement in alternating current circuits.

A consideration of the question of power factor and its effect upon the operation of electrical apparatus involves several simple fundamental laws of electricity. First, the current carrying capacity of an electrical conductor, whether it be in the winding of a generator, motor, or transformer, or a part of a distributing system, is limited by the heat of the conductor, this being true, any condition which requires the passage of a greater current for the transmission of a given load reduces the capacity of the apparatus of the system of which the conductor forms a part. Second, the loss of energy in a conductor carrying a current, whether it be in the windings of a machine or a part of a distributing system, is equal to the resistance of the conductor multiplied by the square of the current flowing in it; this being true, any condition which increases the current necessary to carry a given load increases the loss of energy proportional to the square of the increased current. Third, the drop in voltage in an electrical conductor is the product of the resistance of the conductor and the current flowing, so that any condition which increases the current necessary to carry a

given load, increases the drop in voltage, thereby making the voltage regulation poorer.

The causes of low power factor are mainly lightly loaded induction motors and transformers, electric arc furnaces or other inductive apparatus. It will be seen, therefore, that the causes of low power factor are in general the greater part of the load upon the alternating current generator.

Electric motors are frequently bought and sold on the plan of "get them large enough." When a man purchases motors much too large for the load to be carried, he makes a bad investment, for the following reasons: (a) The larger motor costs more than one of the proper size; (b) The larger motor lightly loaded, consumes more power in carrying the load than one of the correct size properly loaded; (c). The larger motor partially loaded operates at lower power factor than the correct size fully loaded.

Every industrial plant, regardless of whether it generates its own power or purchases it, should make a careful survey with the proper instruments to determine the power factor of its load devices and should arrange to re-group and change its load so that the motors and other appartus are operating at the highest possible power factor. The method of making such measurements will now be described, assuming that we are treating a three-phase circuit.

For instantaneous determination, a poly-phase indicating watt meter, a voltmeter and an ammeter should be connected in the circuit of the device in the test, care being taken in all tests described in this paper to make sure the instruments are of large enough size to indicate the load in question. From the instantaneous observation of these three instruments the power taken by the device and the power factor of the device may be determined as follows: The reading of the ammeter times the reading of the volt meter times the factor of 1.73 will give the total volt amperes input to the load. The reading of the watt meter will give the true power in watts and these watts, divided by the total volt amperes, will give the power factor of the load, at the instant of test. If it is desired to determine the power and power factor over a long period of time and it is desired to know the variation in load and power factor during this period of time, a graphic ammeter, graphic volt meter and graphic watt meter should be connected in the circuit to the load and the readings of these totalled, as explained for indicating instruments. As stated above the behavior of the load at any interval may be determined. To obtain the average power and average power factor for a period of a week, month, etc., recourse may be had to the integrating type of device which would consist of one poly-phase watthour meter, so connected as to measure the true power and a second watthour meter, with a special form of transformer, arranged to read the so-called reactive or waste power. From these two readings a simple calculation will give the average power factor of the load during the period of test. If a survey of each load consuming device shows such devices operating at power factor much under unity, steps should be taken to overcome this condition by a re-arrangement of the load.

The results obtained from tests of motors or other devices with graphic instruments have other values than merely a record of the power consumed or of the existing power factor. These records quite often bring to attention matters that would perhaps otherwise go unnoticed. There may be defects in the machines to which a motor is connected that are not in themselves serious enough to prevent the operation of the machine, but this defect may require a greater input to the motor than if the machine was in perfect condition, resulting in a needless waste of power. Further, such records, if secured at regular intervals, serve to indicate whether the machine being driven by a motor is operating in normal condition, thus anticipating breakdowns which might cause considerable loss of production.

Idle machines mean not only loss in production, but loss in wages while men are idle. Systematic tests of the various motors used in a plant will indicate whether such motors are being utilized to the best advantage or whether there are a number of idle periods in the operation of the driven machine. Graphic records will also show whether men are starting work promptly and working up to the regular quitting time or are losing time at these periods.

When installing instruments for any purpose, consideration should be given to the class of load to be metered. For example, in attempting to obtain the total load on some air compressors driven by 3-phase motors, it was found that the pointer of a certain type of graphic meter, which operates on a relay principle, would remain at any point on the chart that it was moved to by hand, regardless of the total load passing through the meter. An analysis of the conditions showed that the load changes were varying rapidly, within, however rather narrow limits, and the relay within the instrument was naturally vibrating up and down with the rapid load changes. These vibrations were so rapid that the instrument pointer control device was not operating properly, hence the pointer did not give a true indication of the load. As a general rule electro-dynamometer instruments, either indicating or graphic, will be found satisfactory for most purposes.

There are certain precautions to be observed in the use of instruments that it seems worth while to call to your attention. Modern instruments, as a class, are so designed and constructed that they will stand a great deal of service under severe conditions if given proper care and guarded against abuse; and it is certain that the larger portion of the difficulties which arise in instruments is the result of conditions which the user could have guarded against had he given the meter a little preliminary thought. It is not possible in a brief paper to compile a complete list of things to be avoided or all other things which are equally important to do, but as a general thing the following precautions should be observed.

Instruments should be handled gently and should receive no jar or blow from contact with table, bench or other objects in order to avoid damaging the fine points of the pivots or the polished surface of the jewels. A common practice which is very detrimental to pivots and jewels is that of dropping instruments into their carrying cases. It is preferable to lay the carrying case on its side and slide the instrument slowly into the opening. Also, instruments should be protected from particles of dirt or lint which are apt to get into the instrument and cause friction.

Instruments should not be placed upon a bench or other support which is subject to vibration from adjacent machinery and when instruments are connected into a circuit the leads should be so arranged that the instruments cannot be pulled from the table. One of the most common errors developing in the use of in-

struments is the proximity of stray magnetic fields, "these fields coming from conductors, other instruments, heavy masses of iron, or from dynamos and motors." It is best to always place the instrument as far from such fields as possible and to twist together all of the leads connecting the instruments into their circuits.

Before connecting any instruments into a circuit, one should make certain that the instruments themselves are of sufficient capacity to properly carry the load it is expected will flow through them. For direct current testing it is advisable to have a voltmeter with three ranges, 150, 300 and 750 volts. Direct current ammeters are in effect very low reading voltmeters and these milli-voltmeters are connected across a low resistance meter called a shunt; a proportionate share of the main line current flows through the milli-voltmeter and the remainder through the shunt. Care should be taken that the milli-voltmeter is properly adjusted to be used with the particular shunt and that the proper leads for connecting these two devices together are used, as the leads represent a portion of the milli-voltmeter circuit and are a part of the adjustment.

In alternating current testing it is advisable to have a voltmeter with three ranges, 150, 300 and 750 volts; an ammeter wound for five amperes, full scale, and a wattmeter (either single-phase or poly-phase) that has a current coil is wound for five amperes, full scale, and potential coils wound for 150, 300 and 750 volts. For making tests where the current rating is greater than that of the instruments, a set of current transformers of various ratings should be kept on hand. These current transformers consist of a device having two separate windings, the heavier winding being connected in series with the line and the final winding being connected to the instrument; in any current transformer there is a definite relation between the heavy or primary winding or the fine or secondary winding and this relation is such that when the primary is fully loaded, there is a current of five amperes in the secondary. This relation is known as the ratio of the windings. For voltages above 750, potential transformers maybe used and these transformers also consist of two windings, one of which, the primary, is wound to be connected across the circuit to be measured, the other winding, the secondary, being connected to the potential circuit of the instrument, the relation between the two windings of the potential transformer is such that with full rated voltage on the primary winding a voltage of 110 volts will be obtained from the secondary winding.

When making any tests a careful record should be kept of the instruments used, the accessories used and a brief statement of the condition of test. It is extremely important that careful notation be made of the accessories used and of their rating and care should be taken that the actual readings of the instrument are multiplied by the proper factor; which factor will include the ratio of the current or potential transformers, or the reading and ratio of the shunts.

DISCUSSION

P. T. Vanderwaart*: I believe that the development of electric meters has been one of the most important factors in the rapid progress which the electrical industry has made. Electric metering is to the electric industry what the printing press has been to civilization.

In opening the discussion, I desire to call attention to the very interesting inspection trip to the Meter Department of the Metropolitan Edison Company and the excellent paper given by Mr. Pratt should bring out a very active discussion.

Industrial plants are similar to a central station on a small scale; in fact, some plants are even larger than small public utilities. In such plants energy must be distributed and accounted for to a good many departments, and most of this is done through the medium of meters, supervised by a meter organization. However, the development of this end of industrial plant work lags behind the same work of the public utility. Public utilities have taken the lead in the science of apportioning the cost of their output and now charge customers on the KVA basis.

A. J. Standing*: I desire first to congratulate Mr. Pratt on the remarkably clear and concise manner in which he has handled the subject of Metering of Power before this somewhat mixed audience, without having recourse to the complicated mathematical formulae involved, which I understand he is well equipped to handle.

The speaker has referred in detail to the subject of Load Power Factor and its bearing on the generation, transmission, metering, and selling of power. This is very important and is being more and more recognized as an economic factor to be considered in the production and distribution of A. C. power.

The effect of probable System power factor on central station and transmission costs is such that the present so-called power factor bonus and penalty clauses appearing in power contracts are a step taken by the Power Companies toward the ultimate betterment of power factor conditions over their systems. The bonus feature in the form of a rebate on power bills on the basis of improved power factor is an item worth taking into consideration by every power user, and while not as attractive, nevertheless the penalty clause is important as a means of bringing home to the power consumer the questions involved in poor power factor, and causing him to look for a remedy.

Your chairman, in referring to these meetings of the Philadelphia Section away from Philadelphia as "Taking the Show on the Road," was taking a dig at me because I did not altogether favor the idea and even now I only admit the success of our few attempts to be due largely to the work done by our Secretary and the local representatives who have been instrumental again this evening in bringing Reading to our meeting in such gratifying numbers. I want to say to you engineers of Reading that the work done by our Philadelphia Section of the Association of Iron and Steel Electrical Engineers in meetings of this kind is being duplicated by the other four Sections in Pittsburgh, Cleveland, Chicago, and Birmingham, to the end that we may all grow in knowledge of the subjects involved in or akin to our normal activities.

H. S. Rooney†: I cannot add anything to what Mr. Pratt has said, as I have only been in the Department of Meters about four years. My experience with meters had been very pleasant and five years ago the Meter Department in Lebanon had meters and only meters, but during the past year and a half they had

*Electric Engineer, New Jersey, Zinc Co., Palmerton, Pa.

*Superintendent, Electric Department, Bethlehem Steel Company, Saucon Plant, Bethlehem, Pa.

†Superintendent of Meters, Metropolitan Edison Company, Lebanon, Pa.

gone to the fore and under the guidance of Mr. Pratt, I feel that the Meter Department has been brought up on an A-1 basis in respect to the metering of electricity, as you no doubt noticed on your inspection trip this afternoon.

E. B. Wagner*: I am pleased to be the guest of the Iron & Steel Association and to have listened with interest to Mr. Pratt's paper.

Our company is one of the large number of industrial concerns throughout the country who used central station power, and, as the metering of this power was not one of the main items of their business, they were not able to put the time or the organization on meter equipment, as would a central station whose entire revenue depends on the reading of the meters. I think it would be interesting to a number present if Mr. Pratt would outline a sample meter department organization and equipment for an industrial plant.

H. K. Hammond†: I wish to relate some experiences with the old chemical meters: During my employment with a certain Central Station, the metermen were often called upon to do other than meter work, and one cold winter day they were detailed to thawing out frozen water pipes with the conventional outfit, consisting of a 25 K. W. Transformer and Water rheostat. In one instance, after the pipes had been thawed out and the water started to flow freely, the owner, a foreigner, rejoicing over the ease in which we did the job, said how much did he owe us, we told him fifteen dollars ($15.00), he explained *that was too much,* the Boss explained that if he did not pay the bill, he would have the men *reverse the current and freeze him up again.* He paid.

L. D. West‡: I am interested in the human side of engineering, and some of my most helpful experiences have been associations made with the Iron and Steel Electrical Engineers, who I find to be a wide-awake bunch, doers and helping immensely to develop the application of electrical power to various uses. One of the greatest benefits of the Association is the interchange of ideas between the men, which will broaden all of us and make us more useful in this field. As an illustration of this, I bring out the value of such acquaintances in affording a means of getting hold of efficient men in an organization. In order that the Metropolitan Edison Company could have an efficient Meter Department, it necessitated a continued search for the right man, until finally Mr. Pratt was secured. In the same way, the company also wanted a man who had considerable experience in steel mills, as this line of work forms an important branch of the utility business, and after considerable effort, Mr. Baker was secured. The Metropolitan Edison Company has tried to develop an Industrial Power Service Department whose function will be to come into contact with the larger power customers and give them the benefit of any practical experience which this department may have had in the application of electric power to industrial uses.

On behalf of the Metropolitan Edison Company, I wish to thank the chairman and members of the committee for the opportunity of showing them the Meter Department, assuring you it is one of the strongest factors in helping the Metropolitan Edison Company to co-operate with its customers. You know that the Governor advocates the extension of electric service to everyone and our company is always trying to render the best possible service to the people in its territory.

G. W. Quentin*: "Unfortunately I was unable to attend the inspection trip this afternoon, but if what I have heard is correct, the demonstration was not only interesting but instructive, and I believe the Metropolitan Edison Co. should be congratulated on their efforts. We have listened to considerable discussion from the engineering side, and I would like to make a few comments from the commercial side. How many of us realize that the Electric Meter is what stands between our companies and our customers? Therefore, we should take steps to see that our customers thoroughly understand them and make full use of them and where they have meters of their own, see that they keep them calibrated and in good repair.

About two years ago the Duquesne Light Company installed a power factor clause in its power contracts. This clause provides for a very handsome bonus for power factors higher than 75% and penalties for power factors below this point. At the present time we have about 50 large customers that are on this rate and they are all receiving a very handsome bonus, in some cases they have installed equipment to bring up their power factor and in other cases it has only meant a little more careful operation of their equipment.

When we first started this rate we visited our various customers and in co-operation with their engineers made studies of their installations. The thing that impressed me the most in these visits was the little attention that our customers pay to the meters that they have installed and even in some cases where they use them to their accuracy. Very seldom do you find a customer that makes a periodic check on his meters. In some cases we found power factor meters showing leading power factor when they were really running at a lagging power factor; in another case we found a customer that had installed a synchronous condenser some years ago to reduce the line losses to their induction motors and ever since this machine had been installed they had been running the machine itself at unity power factor. This customer's power factor was found to be around 60%, and after we showed them how to operate their condenser, their power factor was raised to better than 90%.

We have also found cases where we have had need of using the customers' meters and we have had some cases where customers kept such good care of their meters that they could be used for billing purposes during the time that ours were out of order.

Our company is very much sold on power factor correction right at the customer's premises and we have been able to considerably increase our average power factor on our system since the installation of our power factor clause. We feel that it is very profitable for us to work with our customers along these lines and make whatever tests that are required and even in some other cases we have worked with privately operated plants.

In closing, I want to thank the Philadelphia Section for this opportunity of being present at this meeting, and also want to congratulate Mr. Pratt on his excellent paper."

*Electrical Engineer, The Lehigh Valley Coal Company, of Wilkes-Barre, Penna.

†Superintendent of Meters, Metropolitan Edison Company, Reading, Pennsylvania.

‡Assistant General Manager, Metropolitan Edison Company, Reading, Pa.

*Power Sales Engineer, Duquesne Light Company, Pittsburgh, Pa.

G. W. Keenan*: "As a guest of the Association, I greatly appreciate the results of its efforts to stage a meeting of this type. Certainly Mr. Pratt is to be congratulated upon his manner of handling the subject for this meeting.

"There is little that I can add on the actual meter story itself, but the discussion on power factor, which has developed, is extremely interesting, current and pertinent to the paper, as well as to the audience.

"Few managements, or even engineers of industrial organizations, appreciate the varying effects of power factor which have been discussed and even fewer appreciate the following effects which have not been covered in this discussion. On an inter-connected system of some size, power factor regulation becomes an important factor in the efficient distribution of load between generating stations. It is necessary at many times to install synchronous condensers out on the network simply to correct the power factor sufficiently to allow of efficient generator operation. In many instances, it is necessary to operate generating equipment at inefficient stations in order to correct power factor in the particular district in which the station is located.

"I am wondering why with this audience Mr. Pratt did not touch upon the types and use of demand meters."

Geo. H. Schaeffer†: Mr. Pratt has delivered a very excellent paper on a very difficult subject—and put it in such a form as to be readily understood. I feel that the paper will be a valuable addition to the Iron and Steel Engineers.

It was a pleasure to go through the meter laboratory and view the splendid equipment for calibrating and testing all the various meters and the facilities for doing it more accurately than when chief dependence was placed on the human element. It was further very interesting to note the saving in time by the use of the new method—meters that formerly took several hours now being tested even more accurately in that many minutes.

The accuracy which Mr. Pratt maintains with his meters—deserves our commendation—and will go a long way in establishing confidence among us Reading folks. Nothing in the selling of electrical power, is more important than its proper measurement. Our company consumes normally 2½ million K.W.H. per month—we maintain our own check meter—I want to add that we have the fullest co-operation of the Meter Department whenever there is an apparent discrepancy —our meters check—on last month's record within 9/100 of 1 per cent.

The ordinary meter single phase 110 Volts is made up of 341 parts and is sold for approximately $7.60. This represents the stage of meter development, and I think it is truly remarkable when we take into consideration the accuracy of the instrument.

Referring to power-factor ours varies from 85 to 97 per cent with a load factor of approximately 55 per cent.

I would like to say just a few words about the Reading meeting. The attendance tonight shows that it has hearty approval—the same may be said of last years' meeting. I believe we Reading folks are particularly fortunate in having the meeting here. I want to express thanks to out-of-town friends for helping to make it a success. Let's keep the meeting in mind for next year, and make it an annual affair.

H. B. Pratt: Relative to the question of the damping of graphic instruments, the amount of damping to be used depends upon the amount of variations of the load. If these load swings vary not over 20 per cent of the scale, the average damping oil supplied with the instrument is sufficient. If the maximum swings are greater than 20 per cent, and less than 40 per cent, a mixture of one-half oil and one-half glycerine will usually prove sufficient. For variations of greater intensity than 40 per cent of the scale, the best damping that can be obtained is with pure glycerine in the damping chamber.

"With reference to the question of demand meters, it is rather difficult in a meeting of this kind to explain all the types in use, but I will try and give a brief description of the main types. Demand meters are used to determine a main load in kilowatts for a definite time period; one method of obtaining this demand is by using the ordinary graphic instrument and selecting from this chart the highest demand for the pre-determined time interval and use a planimeter to obtain the average area of the chart for the time selected, and from this average area calculate the mean heighth of the line to correspond to the integrated portion of the curve. A second type of demand meter consists of a watthour meter combined with a form of graphic meter in which the stylus or pen is geared direct to the watthour meter train; the stylus being moved up the scale of the chart according to the revolutions of the watthour meter. The chart on this meter is driven by an eight-day clock and by means of additional gearing on the clock, arrangements are made so that the stylus can be disengaged from the watthour meter train and returned to zero. The period during which the stylus moves up the chart and then returns to zero can be pre-determined, and this time interval is usually 5, 15 or 30 minutes. This type of instrument will show at the end of the month the actual demand during each 15 minutes of the month, with approximately the correct time at which the demand occurred. It has one disadvantage—that the maximum demand cannot be obtained by instantaneous observation, it being necessary to wait for the full time interval to determine what this demand is. A third type of demand meter will give the maximum demand during the month for a pre-determined time interval, but this type does not give any record as to when the demand occurred. This type consists of a watthour meter and a separate pointer geared to the watthour meter train, this pointer moving over a scale and carrying with it a second pointer. At a pre-determined time interval, which time is usually obtained by means of a synchronous motor (which motor is part of the device and is enclosed with it) the first pointer is returned to zero and the second pointer remains at the highest point reached during the month.

"With reference to complaints, I would state that the number of complaints received are now relatively small. The modern alternating current watthour meter is an extremely accurate device and it will retain its accuracy over a long period of time. Out of a total of 26,000 meters on our lines, we average about one complaint a day and of these complaints in over 90 per cent of the cases, the meters are found correct. I would like to state here that the Public Service Commission of Pennsylvania allows

*Chief System Operator.
†Electrical Superintendent, Carpenter Steel Company, Reading, Pa.

the utilities a 2 per cent error in and adjustment of their meters, but we go further than this and insist that all meters tested either in the laboratory or on the line, should be corrected within ½ of 1 per cent, in other words, our accuracy requirements are four times as great as the Public Service Commission rules require us to maintain."

Electric Repair Shop Practices of the Pittsburgh Railways Co.

By L. J. KING*

EQUIPMENT must be in use in order to obtain the largest possible returns on the capital invested in it. This principle applies not only to the electric railway industry or the iron and steel industry, but to all fields of commercial endeavor.

The work of repairing and maintaining the equipment is of vital importance. This work is often the hidden factor determining the profit and loss of any company. The importance of maintenance work is magnified in the electric railway industry. The shops of electric railway companies are carefully organized to efficiently handle the large volume of maintenance work.

The practices and procedure of motor repair work in the Homewood Shops of the Pittsburgh Railways Company have resulted from a careful analysis of the electrical maintenance problems of a large scale. The volume of work may be readily gained from the following figures for the year 1923:

Number armatures rewound	1,900
Number armatures repaired	5,000
Number field coils wound	2,700
Number field coils repaired	2,900
Shells tested	2,727
Motors tested	2,968

The organization necessary to handle this comparatively large amount of work is divided into two departments; namely, the winding department and the motor test and repair department. These two departments work in conjunction with the machine shop. The winding department employs 25 girls and 36 men, under the supervision of one foreman and one assistant foreman. The motor test and repair department employs about 25 men, under the supervision of one foreman.

The winding department does all the electrical work pertaining to the armatures, including the commutator undercutting work. This department also winds armature coils and main aud auxiliary field coils. The motor test and repair departments remove the armature from the shell, repair shells, put in new field coils, put armature in shell after repairing and test all equipment before it is sent out on the road. The machine shop does all machine work necessary to take care of all the mechanical parts of motor.

The procedure in handling the motor may be briefly described as follows:

The motor is removed from the truck and the armature is taken from the shell. This work is done on the motor and test floor. The shell is cleaned by a jet of compressed air and is then painted with a quick-drying black insulating varnish. The shell is examined for mechanical defects. Worn housings are rebored and oversize bearings used. The field coils are then tested for shorts and grounds. In case a field coil is found to be defective, it is removed and new one or repaired one substituted for it. The poles are then tested for polarity.

The armature, after being removed from the shell, is inspected for mechanical defects. In case any one of the following conditions exists, the practices of Pittsburgh Railways are as follows:

1. Bent shafts are straightened by a hydraulic press.
2. Bad keyways in shaft are welded and then cut, or if beyond repair, the shaft is scrapped.
3. If thread is stripped for pinion nut, a new thread is chased and special nut applied.
4. Loose bearings are scrapped.
5. Allowable wear limit on shaft ⅛ inch.
6. If the pinion fits are worn they are welded and then turned to size. This is still in the experimental stage. New shafts are of alloy steel and are finished on a production basis in the Pittsburgh Railways Shop.

The armature is in good mechanical shape before being sent to the winding room. After the mechanical defects have been corrected the armature is tested for grounds by applying 1,200 to 2,000 volts from a portable transformer; opens are tested by the bell system and shorts by the induction method. The results of this inspection are noted on armature tag attached to the armature. The armature is now sent to the winding room to be repaired or rewound. All armatures delivered to the winding room from the test floor are identified by an attached tag which gives the type, serial number, car number, motor number and fault to be corrected. Record of these items is kept in a department ledger. Each type of motor has a separate ledger with a page for each motor number. In this way the complete history of the motor is available from the time it was bought and put in service.

The armature is now inspected for electrical trouble in the winding room merely as a check on the test floor. If the armature is in condition to be repaired it is repaired, but if not, it is rewound. The basis for the decision as to whether the armature is to be repaired or rewound is governed partially, first, by the length of service of the armature as obtained from

*Engineering Inspector, Pittsburgh Railways Co., Pittsburgh, Pa.

the department ledger and second by the rush of work at this particular time.

The first step in rewinding the armature is the stripping. The armature is then sent to the armature winder, who examines the conditions of the laminations and the width of slots. The commutator is tested for short circuits. The commutator is repaired if found to be defective, but in case this involves considerable repair work the commutator is replaced by a new commutator. The commutator is bought completely assembled without a bushing. Insulation of the armature is followed by the application of new coils in the slots. Connections are made to the commutator and soldered. The commutator is filed, retested and the armature bands are applied. The armature is then sent to the baking room where a temperature of 110°C is maintained and after dipping in varnish is baked from 36 to 40 hours and then allowed to cool. The commutator is then turned; the mica is undercut; the armature is given a complete test and then a coat of air drying varnish is applied. In order to prevent the breaking of armature leads and to prevent damage to the commutator by oil and greases, the leads are cemented with a mixture of plaster of paris, dexterine and liquid shellac. The armature is then returned to the motor floor and fitted with bearings. The armature is then put in the shell and then tested by running overload test.

Winding of all coils is done on a production basis. All coils are form wound except field coils which are spindle wound. The coils are wound with double covered cotton wire, care being used to allow proper clearance of layers. The leads are covered with rubber and triple braid and then tied in place. The coils are then wrapped with one layer of cheese-cloth before being impregnated. The impregnating compound is liquefied by passing steam at 100 pounds pressure around it for a period of 36 hours. The coils in the meantime are placed in a vacuum chamber and baked for a period of 12 hours. The vacuum pump is then operated to remove the air and dampness for a period of 1½ hours. The valve in the mixing chamber is then opened to permit the impregnating compound to pass around the coils till all the coils are covered. Air pressure of 60 lbs. per square inch is then applied for two hours to force the compound down through the coils. The air pressure is then reduced and impregnating compound forced back to the mixing chamber. The coils are allowed to drip and are then removed.

The babbitting department of the Pittsburgh Railways Company is undergoing many changes at the present time. The present equipment is being replaced by new electric melting pots, equipped with all up-to-date devices. But the practices in general regarding babbitting may be mentioned briefly. Bearing shells are of bronze with a ⅛ in. lining of babbitt. The shells are cleaned, the machined surfaces that are not to be coated are covered with a mixture of red clay and water. Zinc Chloride is applied to the bearing and it is then dipped into the tinning solution. The shell is then removed from the tinning solution, zinc chloride is again applied and the operation is repeated. The bronze shell is then removed and immediately babbitted. All babbitt used has a tin base. The babbitt is heated in pots by natural gas. The temperature of the babbitt is judged by the use of a pine stick, but lately pyrometers have been installed to give the proper temperature of the babbitt. All bearings are poured in a vertical position. The jig is removed and the bearing is then turned to fit the armature shaft. The allowable radial wear on the armature bearings is 1/16 inch.

A separate department, known as the Electric Repair Department, handles all electrical work other than motor work. Controllers, grids, cut-off switches, circuit breakers and buzzer work are examples of work carried on by this department. Due to the large volume of this work, each man has become specialist in his particular line, thus enabling him to become proficient in the repair of that particular part.

The maintenance work of the Pittsburgh Railways Company has been so organized that practically every emergency can be taken care of. The modern methods used have been the result of past experiences, experiment, co-operation with the manufacturers and of sound engineering judgment.

DISCUSSION

F. W. Cramer*: We have all heard a lot about armature repairs in previous meetings of the association, but nevertheless Mr. King has added something to this store of information. There is one phase of the subject that would interest us that has never been up for discussion, that is, "When should an armature be scrapped instead of repaired?" If an armature needs coils, a commutator and a new shaft, especially the types that have the laminations stacked on the shaft, is a repair job with only the old laminations for a base of repairs a profitable undertaking? Another interesting topic is "when should the core be thrown away and new laminations be used?" After several grounded and short circuited coils, or perhaps a severe rubbing, due to low bearings, this iron short circuits and causes additional heating in the core, due to increased iron losses. If any of those present have investigated this phase of repair work, we would be glad to hear from them.

R. M. Rumbul†: The demand for increased efficieny and lower operating costs to maintain a fair margin of profit in Industry today has brought about a realization of the fact that electrical equipment plays a larger part than ever in decreasing costs and that the proper maintenance of such equipment is a very vital factor.

To obtain the best results, the several factors which contribute materially to the effectiveness of maintenance of electric apparatus are:

(1) Careful and thorough inspection of damaged apparatus by able and experienced workmen.

(2) Definite repair specifications based on conditions as determined by inspection.

(3) Use of high grade renewal parts, especially designed and manufactured according to or equivalent to the regular factory production specifications for apparatus under repair.

(4) A shop job as a whole including workmanship, materials and test that will give a guarantee of performance equal to the original machine.

The average repair shop of the steel plants meets the above working specifications in regard to many points, but undoubtedly there are many limitations in

*Assistant Electrical Engineer, Bethlehem Steel Co., Johnstown, Pa.

†Westinghouse Electric and Manufacturing Company. East Pittsburgh, Pa.

regard to providing ideal conditions, methods, etc., which it would be almost impossible for them to eliminate along practical lines.

It should be helpful to explain the organization and practice which the Westinghouse Electric and Manufacturing Company have found advisable to adopt in the Service Department in the repair of electrical apparatus.

The Westinghouse Electric & Manufacturing Company early recognized the importance of properly maintaining its apparatus and was among the first manufacturers to establish complete service branches in various industrial centers to service their apparatus. There are at the present time throughout the United States twenty-seven (27) of these service branches.

While our organization may differ somewhat from that in the steel mill repair shop, we believe that in either event it is necessary for a piece of apparatus to be repaired to have the proper inspection, both before and after the job is completed. We, therefore, insist that when a piece of apparatus is brought to us for repairs that it is properly inspected by a man trained for this particular purpose. If it is necessary to tear down a piece of apparatus for complete inspection, this is done for the Inspector, who after going over it thoroughly states specifically what repairs are to be made and a copy of the inspection report is sent to the shop foreman with the apparatus in question.

The Inspector is then relieved of any further responsibility with the apparatus, unless during the course of repairs the shop foreman does not agree with his recommendation, in which case the Inspector is called in conference and a decision is reached. After the apparatus has been repaired, it is returned to the Inspector for final inspection and test.

We are continually impressing upon our Inspectors and foremen the necessity of first placing a machine in good mechanical conditions before placing the winding in same. We insist that particular attention be paid to the condition of the cores on both AC and DC machines. Burnt spots must be fixed up either by separating the iron and pouring compound in between the laminations or complete restacking with new iron or distributing the burnt iron, after properly smoothing same, over the whole area of the core, where it is absolutely necessary to do so, in case new iron is not available. The question of properly repairing commutator and testing it cannot be too strongly impressed upon your force. Shafts are checked for proper bearing fit and also for trueness, and if found to be badly out, they are replaced by new ones. We find in some cases keyways and pinion fits are badly worn, the shaft can be built up by electric weld after first taking a slight cut off same and the keyway placed in a new position diagonally opposite the old one. If bearings are found worn, they are rebabbitted on sizes where we find it profitable to do so. On smaller ones, we find it more profitable to replace them with new ones. In rebabbitting bearings we use the same methods, processes and materials as are used in babbitting the original bearings. We are using a pyrometer and find the results obtained more than warrant the expenditure.

All armature cores are properly painted and wherever called for are either sprayed or dipped and then baked in an electrically heated, automatically controlled oven before and after the winding is placed in same. We find that the results obtained from baking armature winding, if the field core and mechanical part of the machine have received the proper attention, in most cases approaches that of new apparatus.

It is becoming more and more apparent that the best results can be obtained from a piece of apparatus maintained as nearly as possible by the use of mechanical parts such as bearings, brushes, brush holders, etc., of the same high standard as originally furnished with the machine by the manufacturer and also when it becomes necessary to replace any of the windings to use the materials, processes, and workmanship of equally as high a grade as in the original manufacture. The methods, processes and materials and workmanship employed in our Service Shops are the same as at the various works where the new apparatus is manufactured. In order that these methods and materials should conform with the latest practices, there has been organized a Renewal Parts Engineering Department. It is the function of this department to apply improvements wherever possible to renewal parts manufactured, especially for parts of apparatus of obsolete design and to revise methods and processes for the installation of these renewal parts, so that the life of same may be increased as much as possible.

In regard to the organization, we believe that there is a distinct advantage gained by relieving the Foreman of the inspection work, as he is then able to devote his entire time to the workmen and workmanship placed on the apparatus while the job is being done and thus better work is obtained.

Our organization is made up of men well trained in the work, and as service work is our regular business, it is essential that we keep an able force of men. We are enabled to do this because of the varied industry we are called upon to serve.

After the equipment is repaired, it is given the usual ground tests. AC motors are checked for reversed and balanced phases and short circuits. DC armatures are given "bug and drop tests." Whenever completed machine is sent to us it is given a running test before being shipped out. In general, our guarantee on completely repaired equipment is exactly the same as on new apparatus.

I would like to leave with you the thought that the importance of obtaining proper results from maintenance work justifies methods, materials and workmanship that will give assurance of a performance equal to new apparatus. With this as a promise, it will assist in determining to what extent a plant is justified in taking action to remove the limitations which they are encountering in their endeavor to obtain these desired results.

F. W. Cramer: I believe most steel mill men will agree that the shop is the best place to do repair work. Due to the fact that well equipped shops for repair work in electrical departments have, in past years, been few and far between, much of this work was done in the field due to lack of shop facilities. Our present practice is to do all work in the shop. Each armature leaves the shop in a steel case equipped with bearings, nuts, and a key. Bearings are not changed in the field nor are coils cut out or grounds removed. These, at the best, are only temporary repairs, and it was found to be cheaper and more satisfactory to change the armature and bearings and send the worn bearings and armature back to the shop. The steel case is a good investment, for in many cases an armature must be rolled or dragged to get it to the motor, and this case insures it against damage until it reaches the job.

A. C. Cummins*: We are to be congratulated on the two papers which have been presented this evening. They bring a number of questions to mind which will perhaps be of general interest. Do many active members receive request from the management of the Plants with which they are connected for information regarding the money invested in electrical repair parts? I believe it is well recognized that many Plants have as much as $100 per motor installed invested in motor repair parts. The question of carrying this amount of money in the inventory account is becoming a matter of considerable concern to our Plant managements. It is, therefore, important that electrical engineers interested in the electrical maintenance problem, give their attention to the matter of giving continuity of service with the minimum money invested in repair parts.

Mr. Rumbul has strongly recommended the purchase of repair parts from the original manufacturer of the electrical equipment. There is no question that factory material is usually a little more refined, more accurately finished, and should enable the repair shop to make a first class job of any repair work. On the other hand, factory parts usually are higher in price, and have the handicap of much longer delivery. If the manufacturers of electrical equipment wish to assist the electrical maintenance engineer in keeping inventory accounts at a minimum they must improve the promptness with which they deliver the material. By improving the delivery they will enable maintenance engineers to reduce the amount of material stocked, and the turn over will automatically be increased, and the questions of our superiors as to why so much money is invested in the repair parts with a turn over of from 20 to 25% annually is necessary, will be answered.

Mr. King stated in his paper that the Pittsburgh Railways Company impregnated both field coils and armatures. I would like to ask if it is their practice to impregnate complete armature after the winding has been installed, or if the armature coils are impregnated only before installation in the armature. Very few steel plants have impregnating equipment. However, many steel mill shops are equipped for dipping and baking. I would like to ask Mr. King if, in his opinion, the improvement in repair practice obtained by impregnating warrants the additional expense in both equipment and labor as compared to the equipment necessary for dipping and baking. I was at the plant of one of the large manufacturing companies just a few days ago and had an opportunity to see how thoroughly modern impregnating methods do protect the insulation of shunt wound field coils from damage by overheating. In the particular shop in question, some men were sawing test sections from shunt field coils with a band saw, the wires were pushed out of the center of the section to determine whether the impregnating material had worked its way entirely through the coil. So thoroughly was the impregnating done that no difference could be noted between a piece of wire taken from the outer part and one taken from the center. Another very interesting feature of this coil sample was the fact that so long as the impregnated cotton covering of the wire remained tightly wrapped on the conductor, it could not be damaged by the flame of a burning match, but as soon as the cotton insulation was unwrapped from the wire, it burned in the air almost as rapidly as ordinary untreated cotton. The heat resisting qualities of this wire when impregnated were remarkable and in so far as could be seen in a rough test of this character, was fully equivalent to asbestos. If it were possible for us to be equally successful in impregnating coils in repair shops, I believe great gains to service records of electrical equipment could be made.

Mr. King also mentioned that the Pittsburgh Railways Company purchased assembled commutator bars not mounted on bushings. This brings up the old question as to whether steel mill shops should purchase commutator bars assembled on bushings, completely insulated ready to install, or should they simply buy the bars and strips, as seems to be the practice of the Pittsburgh Railways Company. It would be interesting to hear an expression of opinion from the active members present on this point.

Mr. King also mentioned that they were using a mixture of plaster paris and dextrine as an oil resisting paste to prevent the disintegration of the varnish by oil on the outer commutator V ring insulation. I can vouch for the efficiency of this material, as we have been using it in our Shop for nearly three years, and there is no question but that it has greatly reduced the number of armatures coming to the Shop with grounded front V rings. It has been tried by one of the other Corporation Plants in this district and I believe their experiments with the material have proved that it is a very desirable method of treating commutators. I believe the Pittsburgh Railways Company will furnish any one the instructions for mixing up this material if they request it.

One other point, which would be interesting in this discussion, is whether we are justified in case of motor failures to change whole motors rather than armatures or field coils as the case may be, when motors fail in steel mill service? The points in favor of bringing the entire motor to the Shop are as follows:

(1) The repair shop personnel is usually a higher paid and more intelligent class of men than those occupying mill maintenance positions. They therefore have more interest in making a thorough job of repairs than the mill men.

(2) Repairs made in the field, with a piece of apparatus shut down are always made under rush conditions, and the care necessary to make a thoroughly workmanlike job in every particular cannot be exercised when the men are being rushed to get the equipment going as soon as possible.

(3) Armatures and field coils stored around the mill to be installed in motors in the case of failure usually are damaged in handling before they are actually installed for service, and for this reason do not perform as well as anticipated. On the other hand, if the complete motor is repaired and assembled in the shop, and sent out on the job as a unit, there is little likelihood of damage due to careless handling.

One other question I would like to ask Mr. King: If I understand correctly, the Pittsburgh Railways Company do not make it a practice to electric weld stripped pinion threads on armature shafts, preferring rather to chase a new thread and then make a special nut to fit the thread. In steel mills, we have always thought it best practice to weld up the threads and keep our pinion nuts standard. It would be interesting to know why the Pittsburgh Railways Company considers it wise to abandon the idea of standardization in this feature of their shop practice.

*Superintendent Electrical Department, Carnegie Steel Company, Duquesne, Pa.

James Farrington*: I would like to ask if the Pittsburgh Railways or any members of the Association have tried the aluminum field coil? I saw some very good literature on an actual condition, but none from steel mill. They claimed the hotter the coil the better the insulation gets.

I would like to ask if the Pittsburgh Railways or associate members have actual figures on spare parts to be carried to motors in service? I realize that would vary with the condition of that service, whether light, medium or heavy, but sometimes we feel we have plenty of spares for certain types and get caught short.

Regarding the methods of handling our armatures: We bring all of them into the shop in steel cases, but we do bunch them together when repairing them, however, we endeavor to return the same armature back to that department. We have all of our commutators baked. We feel manufacturers are in a better position to bake and repair them than we are.

The question vital to us, is: With 25, 40 and 50 degree machines, how can you arrive at a standard and keep inventory down with those manufacturing changes?

F. W. Cramer: In order to get a comparison with steel mill practice, I would like to ask Mr. King how many motors they had in service when 1,900 armatures were changed during a year?

M. R. Armstrong†: Mr. Cummins has brought out that developments in electrical repair shop practice during the past three or four years has not been given special attention before this institute. During this period, methods have been developed and data collected which may not have come to the attention of its members. The company with which I am connected has done some very extensive development work in perfecting dipping and baking processes, and in studying the best method of motor bearing maintenance. In connection with this work, considerable data has come to hand, which should be valuable to the membership in determining whether certain processes, methods and equipment should be adopted. While this data has been collected from electric railway repair shops sources, it is hoped sufficient details will be presented so as to make it possible to compare with and apply it to steel mill practice.

A large electric railway company on the Pacific Coast installed an electrically heated bake oven. At the same time a systematic schedule of dipping and baking armatures and field coils was inaugurated. Of the 1,800 motors in use, 70% had been in service approximately 25 years. Before dipping and baking was inaugurated, failures were running at the rate of about 70 per month. Two years later, after the majority of the motors had been dipped and baked, failures were reduced to about 24 per month. This was a reduction of approximately 64% in failures. The Superintendent of this shop estimated that the total cost of dipping and baking including all labor in removing and replacing the armatures was between six and seven dollars per motor. He felt this expense was amply justified, as the life of the armatures was extended at least five years, and the interruptions to service, due to armature failures were very greatly lessened.

A large New England Company operating in several towns adopted systematic dipping and baking. In one shop, servicing 475 railway motors, the monthly failures were reduced from 150 to 28. In another shop servicing 400 motors, the failures were reduced from 100 to 24.

Another company from records kept over a period of 13 years has made available the following data: Early in this 13-year period, systematic dipping and baking of their railway motors was inaugurated. Before dipping and baking was started their average service of a motor per failure was two years; after dipping and baking they obtained 7 years' service per failure. Looking at this from a financial point of view, using their actual figures on cost and failures on the 300 motors involved, the figures show that their saving each year after paying all expense of dipping and baking was $2,350.

All of the above examples are from railway service, but it is reasonable to assume that any method which will give such results under the conditions of railway service will be correspondingly beneficial in industrial work. It would be of considerable value if some actual figures on dipping and baking steel mill motors were made available and it is hoped that at some meeting in the near future that this data will be presented.

The size and type of oven for this work depends on the number and size of motor to be serviced. All these ovens shown are electrically heated, and have automatic control. In addition to all Westinghouse Service Stations being equipped with such ovens, there are more than 40 such ovens in successful use throughout the country. Electric heat on account of its ease of control, which means very slight cost of labor for attendance, is a very economical heating medium. It is also easy to install, safe in operation and insures good baking results.

It has been impossible to obtain any accurate data on the results obtained by the use of bearings poured under the best possible conditions in comparison with ordinary practice. In talking with the master mechanics of two electric railway shops recently, both admitted that they obtained better life from factory bearings than from their own. They were using Westinghouse renewal bearings poured from automatically-controlled electric babbitt pots. From our experience, we believe that bearings poured correctly, have from three to four times the life of bearings poured under common existing conditions. Laboratory tests have been made which show defintely that bearings poured with the metal either too hot or too cold are very inferior in strength and wearing quality.

The easiest way of obtaining the best possible pouring conditions for babbitt is by means of automatically controlled electrically heated babbitt pots. These can be furnished in 150, 750 and 1,500 lb. capacities. The temperature is controlled automatically within very close limits. The cleanliness and lack of fumes from these pots has a good effect upon the operator in regard to care of this work. Approximately 100 of these pots are in use in various Westinghouse Works and Service Stations.

Orville Buys*: I am a meter man. I have written a little paper describing the principles of the meter itself, but in light of the discussion so far, I am going to forget that paper entirely. What problems in maintenance we have to solve are nearly always done in the field. The meter is just a little thing; it

*Electrical Superintendent, Steubenville Plant, Wheeling Steel Corporation, Steubenville, Ohio.

†Industrial Sales Division, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

*Superintendent, Meter and Tests Department, Duquesne Light Company, Pittsburgh, Pa.

does not amount to a whole lot in production, but it has all of the elements of two kinds of motors; synchonous motors with demand attachment, and induction motor for each phase of a polyphase meter. Three motors on three phase, four wire. A meter is vulnerable to lightning. We have to rewind the current coils of meters quite frequently. The potential coils are made with such very fine wire we never attempt to repair or rewind them. We have 220,000 odd meters on customers' premises, which the law requires us to test at periods varying from three months to three years. The meter tester who does the work in the field, carries with him such parts as pivots, jewels, upper and lower bearings, disks and shafts. When other parts are not correct the work is done in the meter repair shop. We take a meter out, replace it with another and bring back the defective one to the shop. Ordinarily we have a large enough stock to serve 40-odd types and five makes of meters. When we need a special meter, we make it of standard parts, or sometimes special parts. It is better to make up a meter from stock parts than to wait for the manufacturers' delivery, which is usually from three to eight months.

I would be glad to answer questions, but I think you would be better off without the paper I prepared.

A. G. Ahrens*: I am wondering whether we are looking at this inventory problem from the right view-point. Without actual data as to the original cost of your installed electrical equipment and of the renewal parts in your storerooms, it seems impossible to go far into a discussion. But in Mr. Cummins' case, there is a very large amount of electrical equipment installed in his plant. I believe the original cost must have been over $3,000,000. For his plant, an investment of $300,000 in carefully selected renewal parts would seem warranted.

I want to raise the question: What proportion of the original value, or cost, of the installed electrical equipment is a fair investment on account of renewal parts? Ten per cent seems a reasonable value to me. A steel plant is primarily a production proposition, that is, even a slight delay of the motor driven machinery will seriously affect the output of a department or even of the plant. Therefore, it seems logical to look upon renewal parts as "insurance" against delays in your production. And the cost of your storeroom stock of renewal parts should be compared with the total investment involved, which must be kept running. If this view-point is established, a liberal policy regarding renewal parts is justified.

Electrical manufacturers are naturally interested in any discussion concerning renewal parts which are used in the equipments originally manufactured by them. And in this connection, I would like to call attention that your study of the relative merits of renewal parts practices should take into consideration how frequently the "outages" occur. The expense of installing the part is very often greater than the cost of the renewal part. And when production is delayed, the cost of the renewal part often becomes negligible compared to the lost production. Therefore, it seems a fair conclusion to state—when an accident makes a replacement necessary, the renewal part should be of the best materials and best workmanship.

*Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Renewal parts service to customers is an important subject with Westinghouse, and it may be of interest to know that some renewal parts are carried in 29 district warehouses.

John D. Scully*: Mr. Cummins spoke about using the plaster paris mixture on armatures. We believe that cut down our commutator grounds about 25%. We bake our armatures, and have been doing that for about six years. We started about the time we started using dexterine.

I was wondering what solution some of the other members could offer along the line of standard coils for turbines. If you have a large turbine and want to be prepared for a breakdown, it will take some time to get coils from the factory, so the thing to do is to keep them in the storeroom. If you haven't used the coils for some time, I understand from manufacturers the life has gone out of the insulation. How can we keep those coils so they will not deteriorate?

We have repairs to make on cranes, ore bridges, etc. We found case-hardened steel saved us a lot of money. We tried manganese, also ordinary rolled steel, and we found the case-hardened wheel far superior to anything we tried. At one of the other steel plants in the Pittsburgh district, they tried them, but did not have such good success.

I agree with Mr. Cummins that the repair shop is the place to do repair work, but we have so many different types of motors, I do not know how we could arrange to get them in. In some departments we do take them down and have competent men on night turn able to put these motors in good shape and found they can do the job better and quicker than if brought to the repair shop. That would be a case of training the men to understand mill conditions.

A. C. Cummins: Mr. Scully has just mentioned a point which has brought one to my mind. It is not related to the discussion of the evening, but I think it may prove of interest. Two cranes on old runways were wearing track wheels at a very excessive rate. Wheels frequently had to be replaced after less than one month of service. Rolled wheels were used, hoping that they would help solve the problem and later heat treated wheels were tried, and while the higher grade of material used in the two latter types of wheels increased the life considerably, the replacements required were still prohibitively costly. It was finally suggested that if these two cranes could be kept in line, the excessive wear would disappear. Both cranes were old and were scheduled to be torn down in a year, and it was, therefore, thought that it would be safe to weld the trucks solidly to the girders, and thus insure proper alignment. This was done and after the work was completed no track-wheels were changed on these cranes until they were torn down, some eighteen months later.

In this case the life of the wheels was multiplied by nine times by making the crane so stiff that it was impossible for it to go out of alignment. A number of other cranes have been welded, and in every case it has been found that greatly increased track-wheels life resulted.

W. T. Chappell†: The recent purchase by the Philadelphia Company, of the property formerly owned by the American Locomotive Works in Manchester,

*Assistant Superintendent, Electrical Department, National Works, National Tube Company, McKeesport, Pa.

†Supervisor, Duquesne Light Company, Pittsburgh, Pa.

should give the public, depending upon our utilities, an idea of what we are endeavoring to do in the way of effecting continuity of service.

The property entails over ten acres and houses the Sub-Station Department shops, the Meter and Tests Department, the combined stores of the Pittsburgh Railways Company and Duquesne Light Company and Pittsburgh Railways shops.

Geographically, the property is located in the center of our power ring which, for obvious reasons, brings about considerable economy in the transportation of materials.

On the western boundary of the property, we have two railroads and in addition, river shipping facilities, which will no doubt be developed later.

The Sub-Station Department shops, upon which this paper centers, contain about 33,000 square feet of floor space, and are divided into three divisions, namely: Construction Division, Motor and Appliance and Transformer Division.

The Construction Division employs about 100 men, 10% being located in the shop and 90% in the field.

This division is continually employed in installing, remodeling and maintaining sub-station equipment in sub-stations, power stations and on customers' premises.

The shop section of this division fabricates practically all the steel used in this work, upon order of the Engineering Department.

A point of interest in the Construction Shop is a No. 13 Pels combination shear, punch and angle cutter of German manufacture.

The work this shear will do is as follows: Punches ¼ in. to ⅞ in. holes in steel up to ½ in., cuts 3 in. to 6 in. channel, cut 1 in. to 4 in. by 4 in. angle iron ¼ in. to ½ in. thick, cuts rounds and squares from ¼ in. to 2 in., shears plates up to ½ in. to 2 in., shears plates up to ½ in.

The Transformer Division employs about 25 men whose activities are in both field and shop.

Upon receipt of a new transformer, it is tested for core loss and ratio, given a serial number and placed in stock ready for issue.

When a transformer is removed from service, it is overhauled in the shop, thoroughly tested and placed in the storeroom for re-issue.

In this case the overhauling may vary from a general cleaning and painting to complete rebuilding from the core outward. In either event, however, the transformer is placed in stock in the same condition as when originally purchased.

Transformer oil is a large factor in transformer maintenance and new problems are confronted daily, in the ways and means of reclaiming oil. At this time we are using filters and centrifugal apparatus in the separation of water and other foreign material from old oil.

We expect to increase our oil handling capacity in the near future, at which time we will have another building for this purpose and additional equipment.

The Motor and Appliance Division, employing about 50 men, is divided into three sections, the Motor, Winding and Repair, and Lamp Sections.

The Motor Section repairs a big proportion of all the motors and auxiliary equipment used by the company in the Power Stations and Sub-Stations, and also motors rented to customers on lease agreement.

The equipment repaired varies in size from the smallest motor to 7,500 K. V. A. Syn. condensers, used in Sub-Stations for power factor correction.

As was stated, in connection with transformer repairs, motors go through the same testing routine and are considered as good as new when they leave the shop.

The Motor Section also repairs induction feeder regulators and auxiliary equipment used therewith.

The Winding and Repair Section activities are probably the most varied of any work on the property.

Household appliances, from toys to electric ranges, are repaired in large numbers. Inasmuch as most appliance repairs are ordered by the female member of the household, it goes without saying that numerous difficulties are encountered, in which we are always wrong.

We also conduct special tests on appliances upon order of the manager of the Equitable Sales Company. As an example, a new make of washing machine is sent to the Winding and Repair Section for test. Clothes and water are placed in the machine in accordance with specifications supplied by the manufacturer. The machine is then operated day and night continually until it has run equivalent of two years operation in ordinary use. The washing machine is then completely dismantled and all parts thoroughly examined for wear, grease and oil leaks, etc.

All new makes of appliances are put through this same routine so that when adopted by the Equitable Sales Company, the customer is assured that we have investigated the appliances we sell, and are ready to stand back of them.

This Section also repairs choke coils, oil breakers, disconnects, pole top switches, arresters, electric drills, electric hammers and other tools, and within the near future, we expect to have large tanks set up for the wholesale cleaning of insulators.

In the machine shop, all motor bearings are made, spud rods are turned out and various mechanical and electrical devices are developed for experimental purposes.

One of the latest devices made up was a measuring tape testing machine. All measuring tapes used by the company will be tested to make sure that the linen is not a conductor of electricity.

Coil winding is one of the largest activities in this section. We handle wire from No. 40 up to ten strands of the largest strap wire. The general work consists of winding series and shunt coils for meters of all descriptions, arc lamps, household appliances, relays, motors and transformers.

To carry on this work, a large stock of wire is carried much of which is in special flat sizes. A card record system of winding specifications is maintained as well as a stock of molds upon which the coils are wound. Our equipment consists of five winding heads and a coil puller for motor and armature work. Along with the coil work we have two electric ovens which are not in operation at this time, but will be very soon.

The small oven is 12' by 14' by 9' high and has an input of 50 KW at 220 V. The heat is automatically controlled and a temperature of 125°C. is maintained. As the greater part of our coil work is large compact transformers and armatures a high temperature is necessary, first to thoroughly dry out existing moisture on the cotton covering, and to expand the coil so that the moisture is easily driven off. Then when dipped in the baking varnish, a partial vacuum is created which helps to draw in the varnish and thoroughly saturate the innermost layers.

The large oven measures 14' by 16' by 16' and has an input of 100 KW at 220 V. This oven is also designed to maintain a temperature of 125° C and is automatically controlled. Its function is identical with the small oven, excepting that more head room is provided for the treatment of larger apparatus.

The Lamp Section, the last of the group mentioned, functions as the name implies.

All arc lamps and street series fixtures used by the Company go through this Section for repairs and tests, all new equipment is tested before issue.

In detail, when an arc lamp is removed from service, it is completely overhauled in the shop. New shunt and series coils are installed if necessary, as is also the case with any defective mechanical parts, bushings, etc. The lamp is then tested under the same conditions as when in service, and when placed in stock represents a piece of apparatus as good as new. Four thousand arc lamps were repaired and tested last year.

All incandescent lamps are tested in this section for current input and manufacturing defects, and an idea of the magnitude of this work will be realized when you are informed that last year, 46,750 multiple lamps and 47,300 street series lamps passed through this section.

Forty-six thousand, seven hundred and fifty electrodes were passed upon in 1923, and a small per cent of each crate were inspected for defects. The performance of these electrodes is also followed up.

Five hundred and seventy new tungsten fixtures and 900 old tungsten fixtures were handled last year.

This section also assists with tests conducted in the field and makes up considerable special apparatus as applied to street light-practice.

In summarizing this paper, the following points are brought to your attention:

Ten acres, filled with stores, machinery and highly trained men function daily and at night time, also in emergency, doing its part to promote Pittsburgh's progress.

We cannot carry a duplicate of every piece of apparatus used on the system, but we are maintaining a shop that to date has been able to cope with every emergency met, one idea being foremost in our minds —"Continuity of Service."

T. J. Masterson*: One point not clear to the men, is impregnation. Our experience as manufacturers of coils and reinsulators of field coils of large size, has been that impregnation is better than dipping. To place a bath of coils into a tank and impregnate without heating would be murder, so we have to heat, impregnate and bake coils thoroughly before delivery. Coils are placed in a tank and vacuum drawn under sixty pounds pressure thereby removing the moisture, after which they are impregnated and baked twelve to thirty-six hours, according to coil. You are bound to have a film of varnish, but if not given proper time, it is best not to impregnate. We also impregnate complete A. C. motors and armatures after all windings are installed and completed, but if not thoroughly and properly baked you have a wet varnish throughout the job. If enough time is permitted to bake, the result is a good insulation throughout. This impregnation you fellows should look into, is a worthwhile proposition and cuts repairs considerably. We would prefer doing it with all our rewinding jobs, especially on DC on account of the commutator, but are not always given time to do so. We find on impregnation of asbestos wire we do not get as good results as on DCC, but have cases where commutator wears completely out without any winding trouble on asbestos coils. One of our friends using asbestos coils suggested welding leads to commutator to save him soldering same when overloaded and solder was thrown out. At one time we made a considerable amount of coils for the Pittsburgh Railways Company at a time when their men were swamped and work had to be sent out.

F. W. Cramer: It is not always a case of forgetting to have the spares rewound, as many other factors enter into repairs. While conducting an investigation on armature repairs some years ago, the fact was brought out that there are "runs" on different types of armatures that the repair shop stock is not usually prepared to handle. It seems that, for no apparent reason, a great number of a certain type of armatures will be changed in a short period of time, and then the rate of change will go back to normal. Perhaps the next month an abnormal number of another type will be changed. Unless the shop is equipped to make or get coils on short notice, these runs will cause a delay in repairs, as the store room would not carry sufficient stock to take care of excessive rate of change.

Phelan McShane*: Both Mr. King and Mr. Rumbel, in their papers, have sought to emphasize a point that is very frequently neglected; that is, the care taken in placing the equipment to be repaired in first class shape mechanically. His point in regard to a trained inspector is also one that deserves very serious consideration.

In visiting the various plants, the universal complaint that is heard is that sufficient wages to secure skilled and experienced workmen cannot be paid. Fortunately the service stations are not so handicapped, and it is evident that a very determined effort on the part of the managers of industrial repair shops must be made to secure adequate rates if they are to obtain satisfactory results.

Before adequate service stations were established, the electrical superintendents of the various steel mills were forced to manufacture coils, commutators and other parts, but always they have been handicapped by insufficient volume to properly equip their shops or to provide the skill and experience to secure the same results that may now be obtained through the use of parts furnished by the manufacturer of the apparatus.

While there has been a very marked improvement in the life of apparatus repaired in the industrial repair shops, there is always a very wide discrepancy between the life of the repaired apparatus and new apparatus. This discrepancy can be traced to one or all of three causes: inferior renewal parts, improper methods and unskilled workmanship.

In the past we simply replaced the armature when it failed. Now we replace both bearings and armature when trouble develops in either one. I think in the very near future we will replace the entire motor when trouble occurs. This can be done in most cases without any increase in the time lost in making the change, and without any increase in the money invested in the spare parts, and even if there was an increase in money

*Shop Superintendent, Doubleday-Hill Electric Company, Pittsburgh.

*General Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

invested it would be more than offset by decrease in delays and maintenance cost.

A striking example of what can be done by effecting proper repairs is furnished by one of the larger eastern Street Railway Companies. For years they maintained a very complete electrical repair shop with ever mounting repair costs. Some years ago they turned over to our New York Service Department all of their motor repairmen with an average increase of 100 per cent in the length of time between repairs and at a very marked decrease in repair cost.

In closing, I would like to hear from the members some suggestion as to the best method to secure a comparable record of the life of apparatus between repairs and new apparatus. For instance, we are told that one class of apparatus costs so much per horsepower to maintain or repair per year, while some other class or type costs so much more or less. Obviously this information is very misleading unless the actual running time is given and the nature of the application is also stated. One would expect an 80 "MC" motor on a screwdown to give more trouble than 80 "MC" on a ladle crane. We would also expect an S. K. on a skip hoist to give more trouble than one on a machine tool.

F. W. Cramer: Very few people make it a practice to change whole motors on cranes, perhaps, for the reason that the crane or building over the crane is not equipped to handle a whole motor quickly. In the modern mill motor, where the top half can be lifted off, the old armature rolled out, and the new one put in, the time advantage of changing a whole motor would be small. The big advantage in changing the entire motor would be the assurance that the other parts of the motor, such as fields and brush holders, were in first class condition.

It seems the tendency is towards changing the complete motor.

D. W. McFayden*: We have in our plant, forty-five 150 h. p., 166 r. p. m. motors. They have been running constantly for sixteen years, twenty-four hours a day. Two sets of bearings have been changed on account of wear. These motors have adjustable bearings and flexible couplings.

For the last ten years, we have made it a practice to change all bearings or armatures, DC or AC, on all motors, in the repair shop and not in the mill. A group of five men, with an Electric Truck, take motors to shop to be cleaned or given any repairs that are necessary. In this group, we carry an extra craneman and an extra oiler.

Throughout the mill, we have four Portable Winches, used for changing motors. Where we have a drive that affects the entire mill when down, we keep a spare motor there. We have reduced delays twenty-five percent, and give this system credit for same.

A. C. Cummins: "Were your cranes designed for this system of repairs?"

D. W. McFadyen: "We have a trolley over the crane runway and have 10-37-50 H. P. A. C. motors on cranes."

A. C. Cummins: Further with regard to changing whole motors as compared to armatures or field coils, it might be said that so long as whole motors were changed in one of our Open Hearths, delays were on the decrease. When the period of depression came in 1922, the practice was discontinued and delays and interruptions to crane service and Charging Machines commenced to increase after an eight to ten-month period. The practice of changing whole motors has again been inaugurated and once again the delays are on the decrease. It is difficult to form any definite conclusions from these statements inasmuch as the tonnage produced by this particular Open Hearth fluctuated over wide limits during this time. However, it can be taken as an indication that the changing of whole motors periodically and bringing them to the shop to be thoroughly overhauled will in general improve continuity of service records and decrease maintenance costs.

W. C. McKibben*: On big motors and large armatures, 50 H.P., we make better time by bringing them down and changing them complete.

Jno. E. Cooper†: On our important cranes, such as ladle and charging cranes, where delays cost something, we have spare motor fitted up with countershaft and gears. If motor fails we change the whole assembly at one time; we also do the same on Sunday repairs if we think it necessary to change motor for any reason.

F. W. Cramer: It seems the tendency is towards changing the complete motor.

R. S. Bull‡: I would like to ask the gentleman from Doubleday-Hill when they wound all the Pittsburgh Railway armature coils?

T. J. Masterson: We kept three winders going on Westinghouse E-57. That has been probably eight years ago. At that time you fellows could not keep up in your work.

R. S. Bull: During that hard winter our car service was practically down to about 20 per cent of normal. We kept a floor in the Westinghouse, East Pittsburgh shop busy, turning out 50 motors a week, the Pittsburgh shops worked day and night. The Crescent Electric Company worked all the men they had; and the Doubleday-Hill Company was assisting us; but at no time did any shop or factory furnish all the coils used by Pittsburgh Railways Company.

T. J. Masterson: I should have said "part of your coils."

R. S. Bull: The question has been asked how many motors we have in service. About 6,000 to 6,500. We change almost one-third every year. A great many of these motors which we have changed so often are of this older type 57, which we are now scrapping. The old 56 and 62 are being replaced by box type so we don't have to change so often. We have 100 motors in service for over three years that we haven't put bearings in maybe more than six or eight of them. One gentleman stated that the Railway had started the proposition of changing motors periodically. When a car goes through our shop, we take the motors from under the car, put them through the winding room, test, groove commutators, test the fields, remove the mud from inside the frame, put them together and test them on a testing rack. Two large 220-H.P. motors which are used as generators and motors mainly on 125 overload test. All motors

*Electric Superintendent, Universal Portland Cement Company, Universal, Pa.

*Elect. Supt., Lewis Foundry & Machine Co., Coraopolis, Pa.

†Elect. Supt., Carnegie Steel Co., Bellaire, O.

‡Superintendent of Shops, Pittsburgh Railways Co., Pittsburgh, Pa.

when we first started to test them were running out of our own shops, 15 to 18 per cent due to armature winding. Since the testing floor has been in operation, it runs from 1½ to 3 per cent, and has been up to 5 per cent.

I agree very heartily with men present who change the whole motor. We do that with railway motors as much as possible, and are trying to get far enough ahead so we can do it at all times and in all cases. No matter how good the men are in some of the smaller shops and barns and some of the smaller steel mills, they don't take care of electrical apparatus with the precision that they do in the shops, and that is the reason we believe it is a better idea to change the whole motor, although the transportation charges are much higher.

The reason why we do not renew the threads by welding is that we do not have very much trouble with them. We keep the pinion nut and key attached to the armature shaft at all times. It goes clear through the winding room, and if it happens to be a special nut, it is put on special; so it doesn't make such conglomeration of nuts and threads as you might believe, because there is not very much you have trouble with if you keep it with the armature and then chase the thread on. Sometimes, after welding, it is pretty nearly impossible to chase the thread on.

J. D. Scully: How many types of motors have you?

R. S. Bull: Approximately ten. We have eliminated two in the last three or four years, and are in the process of eliminating three other types within the next year. We find in the box frame motor it is entirely different from the split frame, because the split frame motor, especially when put together by someone who does not understand the electric game, if the halves are not just where they should be there is trouble.

A. C. Cummins: Any particular value attached to cost of motor equipment?

R. S. Bull: We aim at about 10 per cent, but it isn't always practicable. For instance, one storm the last week in June cost $20,000. Weather conditions have everything to do with stock of material we have on hand. We aim to keep a large amount of field coils and spare armatures in the storeroom at all times. We sometimes get caught. We were caught in that bad weather. In Buffalo they did not run a car for 10 days to three weeks.

Impregnation to steel men possibly does not mean what it does to railway motors, because on railways they are operating in dampness at all times, often in rain and snow. Often in new motor, field coils which are heavy copper wire, have to be made into a solid mass in order to stay there. Where you have motors in a shop, they don't get weather conditions, and presumably don't get the contrast of heat and cold that our motors do. I do not believe it is quite as necessary to impregnate. We impregnate field coils into a solid mass.

J. C. Cooper: Most of your trouble is from dampness?

R. S. Bull: A great deal of it. Either the armature or field becomes grounded and you have to change the whole winding position nearly every time; that is why we find it of advantage to change the whole motor.

J. D. Scully: Previous to the low-type car, you were not troubled as much with dampness as you are now?

R. S. Bull: In the old type it was possible to keep covers on them.

J. D. Scully: In the steel mills we probably have 100 different conditions. Your service on railways would probably be like a number of our conditions, but it wouldn't be applicable to all.

A. C. Cummins: Do you have trouble with a film of oil and dirt there?

R. S. Bull: Seventy-five per cent are dry if applied right. We don't have much trouble.

A. C. Cummins: Very few come in for grounded commutators?

R. S. Bull: Very few.

A. C. Cummins: In the older type of motors it seems to be impossible to keep oil from around the commutators.

R. S. Bull: It would pay to have an oil wiper to throw the oil from the motor.

A. C. Cummins: If it could be put in the present frame construction it might not be expensive.

A. G. Ahrens: I would like to say a few words regarding the deterioration of armature coils in storage, which Mr. Scully mentioned. I believe this deterioration is caused by oxidation of the surface varnish, which dries from continuous exposure to the air and causes brittleness. This oxidation of the varnish is particularly severe when the air moves continuously across the surface of the coil.

I would suggest that armature coils be stocked in the containers received from the manufacturer. At any rate, stock those coils in this way which are comparatively inactive, that is, those coils which remain in the storeroom a longer period.

Coils are packed in moisture-proof containers when shipped by the manufacturer. The containers will prevent air from getting at or moving across the coils. They will save the coils from deterioration. I might add, also, that average temperature and average humidity are best conditions for stocking coils. Avoid dry, hot and damp places.

Brent Wiley*: In regard to the practice of changing the complete motor instead of changing parts, where repairs are necessary, it is very important that facilities be provided to do this work with as much convenience and dispatch as possible. During the last several years, there has been a tendency toward increased size and capacity of various mill machinery and mill parts with a corresponding tendency towards increase of size of motor equipment used, and the average motor size is gradually increasing. This is particularly so in regard to cranes, as today there is a proportionately large number of larger sized motors required.

If the Association recommends a general practice of changing motors in case of trouble, it would be well to go on record so that the engineering organizations of the steel companies understand the situation—why such practice is advisable and to what extent the matter should be given consideration in laying out buildings. This would insure that proper facilities for handling the motors were provided and

*Asst. Mgr., Industrial Dept., Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

such items as bedplates and mountings could be worked out so the motor could be changed quickly and to make it easy to line it up and fit the changed motor to the machine properly.

F. W. Cramer: Several of the new mill buildings over the country have been designed with a small trolley running over the cranes. With this it would be an easy matter to hoist an entire motor on a crane. Most of the mills, particularly the old ones, do not have a roof design that would permit this feature. It is usually the case that an "A" frame is rigged up on the trolley that will permit armatures to be hoisted up by means of a block and tackle.

R. M. Hussey*: In this discussion on inventory you are evidently trying to fix the size of inventory in comparison with the cost of equipment installed, and I would like to ask this question. How can you reconcile 10 per cent inventories covering ten different sizes or makes of motors with 10 per cent inventories covering, say, fifty different sizes or 300 different types and sizes? The fellow who has only ten different types and sizes and carries a 10 per cent inventory is out of luck.

A. G. Ahrens: It is a matter of comparative total original costs, that is, a matter of comparative investments. With large users of motors, such as most steel plants are, the investment in renewal parts is not seriously affected by diversity of sizes or ratings. There are usually enough motors of each rating to result in an adequate, and yet economical, investment of renewal parts.

A. C. Cummins: I believe Mr. Hussey is probably right. Assuming that a plant has a million dollars invested in electrical equipment, consisting of modern mill motors in ten sizes, 10 per cent of the value of this equipment is a fair figure for the investment in spare parts necessary to insure uninterrupted operation. I, personally, believe that 10 per cent is a higher figure than would be necessary if the manufacturers kept the repair parts in stock so that we could procure them quickly. On the other hand, the mill having a million dollars invested in electrical equipment, consisting of many obsolete types of apparatus would be justified in carrying more than 10 per cent as insurance, both because the service rendered by the obsolete equipment requires more store material and also because delay in securing parts for obsolete motor is greater. If the Pittsburgh Railways Company has 6,000 car motors in ten different sizes, and they require 10 per cent of their total electrical investment for spare parts I believe steel mill electrical engineers are efficient in the administration of spares, as there are very few who do not have more than ten different sizes and designs of motors to maintain, nor as much as 10 per cent of the total initial investment tied up in store material.

A. G. Ahrens: I have suggested 10 per cent of the total original cost of the installed equipment as a normal storeroom stock of renewal parts. This is for the average steel plant. And the average steel plant, as I know it, has both obsolete and modern motors installed.

It is difficult to say much in favor of obsolete motors, meaning those motors which are no longer the manufacturers' standards. But it is quite likely that obsolete motors are aged, and their requirements of renewal parts larger than motors of current design. Perhaps new mill conditions—greater tonnage requirements—have overloaded them. I would suggest that the electrical superintendent can arrive at the correct basis for handling his renewal parts stock by keeping accurate cost records of the repairs.

If the motors are aged, it is likely their original cost has been depreciated to a nominal book value. This, and large maintenance makes it seem timely to change to modern motors; and select them large enough for present requirements and also for the increased load if greater tonnages are part of the future program for the mill.

In dealing with ledger or book values, be careful to differentiate between depreciated values and original or cost values. Comparisons will be misleading and lead to wrong conclusions, if we are not careful to watch this.

A. C. Cummins: In answer to Mr. Ahrens' remarks, I believe that I have not made myself clear. The point that I was trying to make was that the value of spare parts stocked is not so great in a plant having electrical equipment, consisting of a certain number of electrical units of duplicate design, as compared to a plant whose equipment consists of the same number of electrical units of many different designs. To go a little further, it is possible to imagine a plant having installed 1,000-50 H.P. motors of one type. Such a plant would carry a very small store supply of electrical material. On the other hand, a second plant having a thousand motors of 50 H.P. of a hundred different designs would require an investment in electrical store material of at least five or possibly ten times larger to be adequately insured against shutdowns.

A. G. Ahrens: You are citing a general proposition. It may be possible for ratings to be so diversified as to require greater care in selecting your renewal parts stock. For example, you may have to abandon your rule of carrying in stock at least one spare armature for every direct current rating installed; and carry instead a set of armature coils.

A larger variety of ratings makes it imperative that accurate records of repairs be kept and that these records be used as the basis for selecting the renewal parts stock which should be kept in your storerooms.

Diversity of ratings may be the cause of a burdensome inventory in a small factory, but it need not be in a steel plant or other large user of motors. In the average steel plant, there should be enough motors of each rating to result in an adequate and economical stock of renewal parts. And accurate records of repairs will indicate those motors and ratings which merit standardization and further purchase.

A. C. Cummins: As a matter of fact, auditors are usually interested in the dollars and cents invested, and if they see unusual increases in the amounts of money invested in electrical spare parts, the question of why so much money is tied up in this material is asked, regardless of what relation the store account is to the total amount of money invested in electrical equipment. I believe their question is justified and I think they are particularly justified in asking why large store accounts are necessary when the items do not turn over rapidly. In some lines of mechanical equipment the manufacturers have made it a practice to keep in stock every item required for the repair of the equipment he offers for sale, and it is thus

*Elec. Supt., Jones & Laughlin Steel Corp., Woodland, Pa.

possible for the mechanical maintenance man to keep his part of a steel mill operating with a much smaller spare part investment than is necessary for the electrical maintenance superintendent.

It would seem to me that on account of the diversity of demand that the manufacturer could keep in stock many of these parts at a less expense than it is possible to store them at plant, and he would secure a much more rapid turnover of his money than it would be possible to secure from individual mill supply rooms.

L. J. King: Mr. Bull has covered practically everything that was asked me, except the baking of the armatures. We have no definite figures on value. We measure our return on investment in car miles and length of service. We have found, after baking armatures, we will have them in service for three years, some of them; others may come back within a week. There is quite a varied idea as to the value of it, but in our work we find it tightens up coils in the armature, prevents looseness in the armature from vibration, etc., which is severe on street cars; so that it is advisable by all means. Since we started baking our repair force has been cut from 125 to about 65, and the repair bill is going down fast. We did not go into the mechanical process largely because the steel mill maintenance department is comparatively small. The tendency is now to analyze cost and get basic figures as to whether it pays to do certain repair work or whether to go to the manufacturer. I hope Westinghouse, General Electric, and other electric companies can give us definite figures and prompt deliveries on any work, and probably we can turn over more work to them. But, in general, we find that it pays to have a good repair shop. It depends a great deal on the men, and it can't be over-emphasized that a good workman is worth his weight in gold to any company.

J. Farrington: Any experience with aluminum coils? It seems everyone has sidestepped that question.

L. J. King: No experience with aluminum field coils.

J. D. Scully: About 10 years ago we tried aluminum field coils. They did not answer our requirements at that time.

Electrically Heated Soaking Pits

By B. G. BAILEY*

THE electric heating of soaking pits has been under consideration for more than ten years, and has been the subject of several papers before technical societies, and while on every occasion considerable interest was shown, it seldom went further than "where can we see one in operation." Among those who were not familiar with the technical side of electric furnace design and operation, there was a belief that electrically-heated pits could not compete with gas-fired equipments, and while it was generally conceded that electric pits would reduce the scale on the ingots, many were of the opinion that it was necessary to scale ingots heavily in order to produce a good surface on the bloom. These various contentions remained somewhat open questions until the installation of the Electric Pit at The Donner Steel Company last March.

Since that time several hundred ingots of both carbon and alloy steel have been put through this pit and a comparison of these ingots with other ingots of the same heats put through gas pits, together with a description of the electric pit, is the subject matter of this paper.

Description of the Electric Pit

The pit is 150 K. W. electrical capacity, with outside dimensions of approximately 8 ft. wide by 9 ft. long by 10 ft. high, with internal dimensions of 3 ft. wide by 5 ft. long and 8 ft. deep, holding two 6,800-lb. or 7,400-lb. ingots. The electric heating is accomplished by means of carbon resistors using crushed carbon of approximately ¼-inch mesh, contained in troughs made of carbide of silicon. This type of resistor is the only one so far developed that can operate successfully at temperatures to be met with in soaking pit practice. The power input is controlled by means of special transformers having a number of voltage taps on the secondary, each tap giving a different K. W. input to the furnace.

The resistor units are located in the side walls of the furnace in such a manner that the ingots cannot come in contact with them, the slap of the ingot in

FIG. 1

charging being taken by heavy firebrick walls projecting beyond the resistor troughs, and while the pit has been in service several months, no repairs have been required to these walls nor to the cover, whose brick work is in prfect condition, although heating ingots

*President, Bailey Furnace Co., Alliance, Ohio.

to a temperature of 2,350°F. or above, and at times for experimental purposes, has been called upon to maintain furnace temperatures of 2,600°F.

The transformer equipment consists of a 150-K. W. Packard 25-cycle, single-phase transformer, which was sometimes called upon to carry 50 per cent overload continuously. The meter equipment consisted of a

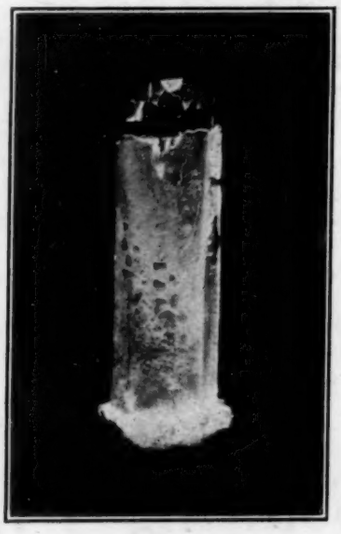

FIG. 2

Weston Indicating Wattmeter, a Westinghouse Graphic Recording Wattmeter and a Brown rare metal couple Graphic Recording Pyrometer, with the couple located in the cover of the pit directly above the ingots. The temperature readings were checked by means of a radiation pyrometer, which instrument was also used to take the temperature of the ingots going to the pit, when they were on the way to the mill, after leaving the pit and while they were in the mill. As the blooming mill was steam-driven, it was not possible to obtain reading of relative power requirements in rolling between electric and gas-heated ingots, but the finishing mill was electrically-driven, and the comparative results on rolling given in Table No. 1 are taken on this mill. Had it been possible to take similar readings on the blooming mill, the relative difference in power readings between the gas and electrically-heated ingots would have no doubt been even more marked.

The loss of metal due to scale was determined by means of an ingot scales located at the entrance to the blooming mill, ingots of both the gas and electric pits being weighed after stripping and before charging in the pits, after heating and before rolling, and finally after the fourth pass in the mill.

Power Required for Heating

While it was not possible on account of plant conditions to operate the electric pit to the best advantage except on a few occasions, the power consumption for heating was well within the figures made before the equipment was installed. For instance, during the month of November, 101 ingots of an average weight of 3.3 gross tons each, were heated, and during this period the power was on the pit 624 hours, but ingots

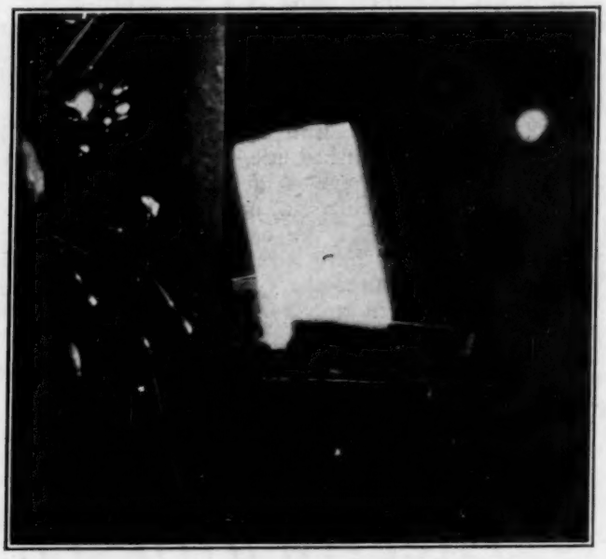

FIG. 3

were in the pit only 92 hours and during this time the pit under these conditions operating at only 15 per cent capacity. Even under these conditions, the total power consumption was only 189 K. W. hours per gross ton of metal heated.

Taking the average practice, however, between November 16 and December 2 charging the pit with power only during the time ingots were in the pit, the power consumption was 80.4 K. W. hours per gross ton of ingots heated when heating two 3.3-ton ingots at a time to an average temperature of 2,316°F., the skin temperature of the ingots charged being 1,660°.

During the period mentioned above on account of mill conditions, it was necessary to hold the ingots in the pit on some occasions as long as 16 hours and 40 minutes, while, under the best conditions, the time in the pit was only 1 hour and 40 minutes, although it was found that an average period of 2 hours was quite sufficient for ingots charged at a skin temperature of 1,600°F. and heated to 2,350°F.

Had it been possible to operate the pit continuously on a two-hour soaking schedule the power consumption would have been considerably under 75 K. W. hours per gross ton, as occasional daily operation showed power consumptions under this figure. It should be kept in mind that the heat loss through the walls of this small pit was large, compared with the

TABLE NO. 1

Comparison of power required for rolling Electrically Heated and Gas Heated ingots. Temperature of the outside of ingots approximately the same by radiation pyrometer.

	Temp. at 4th pass	Temp. at 9th pass	Drop in Temp.	Av. difference in peak load	Av. difference in K.W. hr.
Electric Ingots	2147°	2091°	56°	9% less	25.8% less
Gas Ingots	2118°	2049°	69°		

heating capacity of the pit and that a full-size pit of four 6 ft. by 8 ft. holes would show much better economy. From a careful check on the wall loss of this pit during the period mentioned of the 75 K. W. hours used for heating, approximately 30 K. W. hours were chargeable to wall loss, leaving 45 K. W. hours as the heat actually required for the steel per gross ton, while in a full-size four-hole pit holding 24

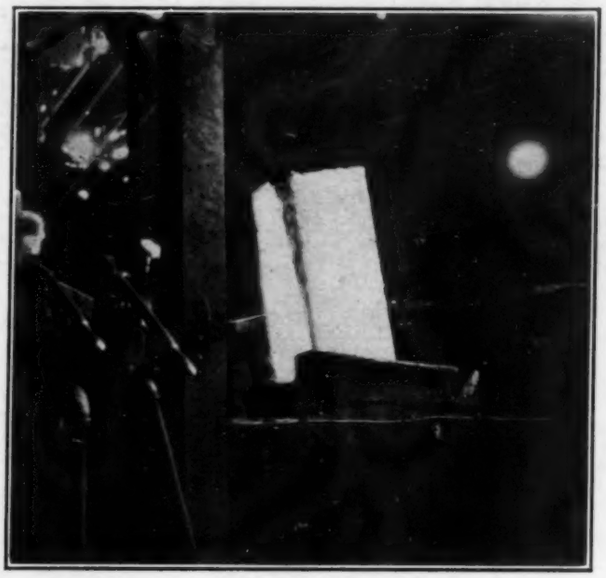

FIG. 4

3.3-ton ingots and operating on a similar heating period the power chargeable to the wall loss per ton of ingots would not exceed 15 K. W. hours per ton of ingots heated, making a total power consumption of 60 K. W. hours per gross ton of ingots put through the pit, when ingots were charged at a skin temperature of 1,670°F. and heated to 2,350°F.

With a higher charging temperature of, say, 1,850°F., which is possible on most steels, the power consumption should not exceed 45 K. W. hours per ton; and with ingots charged at 1,670°F. and heating to only 2,250°F., the power consumption should be under 50 K. W. hours per ton.

When heating cold ingots in a full-size pit, using eight hours as the heating time and heating to 2,250°F. the capacity of the pit would be 10 tons per hour, and the power consumption 330 K. W. hours per ton of ingots heated. This power consumption makes electric heating prohibitive from a cost standpoint on low-grade steels, but on high-priced alloy or high-speed steels, the saving due to the reduction in scale loss may easily compensate for the higher cost of fuel or power for the electric pit. Since, by far the largest tonnage of ingots are charged into the pits at temperatures near 1,670°F., the calculations of power consumption for full-size pits are based on steel going into the pit with that temperature.

These figures appear in Table 2. It is to be noted from this table that when taking into consideration the saving in scale that no fuel-fired furnace can compete in cost with electric heating under the conditions named.

Scale Loss from Ingots

One of the most interesting features of the test on the electric pit was the determination of metal loss in scale. Both electric ingots and gas-heated ingots were weighed before charging into the pits and after the fourth pass in the mill. The average loss of electric-heated ingots was ¾ per cent and on gas ingots substantially 1¼ per cent. The scale loss on electric ingots seemed to be about the same, regardless of the time the ingot was in the pit, indicating that this ¾ per cent loss was caused by the air striking the ingot after stripping and before charging into the pit. In the case of the gas-heated ingots the scale increased as the time in the pit was increased. While the record of loss on the gas-heated ingots in this case was only about 1¼ per cent, it is believed that this figure is too low for average practice, as records taken from a number of other installations of gas-heated pits indicate that a scale loss of 2¾ per cent is more nearly the average loss.

The difference in scale is best shown by Figures 1, 2, 3 and 4. Figure 1 is a 7,400-lb. chrome nickel ingot heated in the electric pit, Fig. 2 is an ingot of the same heat heated in the gas pit taken at the same number of seconds after removal from the pit, as the picture of the electric ingot. Both ingots approximately 2,350°F. Fig. 3 is a 6,800-lb. carbon ingot heated in the electric pit, and Fig. 4 is an ingot of the same heat put through the gas pit. Fig. 5 shows a train of ingots at the temperate at which they were usually brought to the pit, which was about 1,600 to 1,700°F. Fig. 6 shows the top of the electric pit with cover open and an ingot being removed from the pit.

Surface of Bloom

The operation the electric pit demonstrated conclusively that the blooms coming from electric-heated ingots had better surfaces in all cases except, perhaps,

FIG. 5

in such cases where the ingots were very scabby, under such ingot condition there was no advantage in surface condition of the bloom by electric heating.

Power Required in Rolling

Due to the fact that the ingot from the electric pit could be and were heated to the desired rolling temperature, and were perhaps more evenly heated throughout, the power required for rolling electric ingots was less than for gas ingots heated to the same skin temperature, and it as also noted that the peak load on the mill was less when rolling electric ingots

TABLE NO. 2

Comparison of Electric and Gas Heating Costs based on Electric Power at 6 mills per K.W. hr., Coal at $6.00 per ton gassified, Coke Oven Gas at 12½ cents per 1000 cu. ft. Metal losses at ¾%, 1¾% and 2¾% and Steel valued at $30.00 and $40.00 per ton.

ELECTRIC HEATING Ingots charged at 1670° heated to 2350°F		PRODUCER GAS HEATING Ingots charged at 1670° heated to 2350°F.—250# Coal per Ton.	
60 KW. hr. at 6 mills	$ .36	250# Coal at $6.00 Ton	$ .75
¾% Scale at $40.00 Ton	.30	2¾% Scale at $40.00 Ton	1.10
Renewals and upkeep	.10	Renewals and upkeep	.10
Total per gross ton	$ .76	Total per gross Ton	$1.95

ELECTRIC HEATING Ingots charged at 1670° heated to 2250°F		PRODUCER GAS HEATING Ingots charged at 1670° heated to 2250°F.—167# Coal per Ton.	
50 KW. hr. at 6 mills	$ .30	167# Coal at $6.00 Ton	$ .50
¾% Scale at $30.00 Ton	.225	1¾% Scale at $30.00 Ton	.525
Renewals and upkeep	.10	Renewals and upkeep	.10
Total per gross ton	$ .625	Total per gross Ton	$1.125

ELECTRIC HEATING Ingots charged at 1850° heated to 2350°F		COKE OVEN GAS Ingots charged at 1670° heated to 2250°F.	
45 KW. hr. at 6 mills	$ .27	4,000 cu. ft. at 12½c	$ .50
¾% Scale at $30.00 Ton	.225	1¾% Scale at $30.00 Ton	.525
Renewals and upkeep	.10	Renewals and upkeep	.10
Total per gross ton	$ .595	Total per Gross Ton	$1.125

than when rolling ingots heated in the gas pits. It will be noted that in Table No. 1 the average peak load demand was 9 per cent less for electric ingots than for the gas-heated ingots, and that the K. W. hours per ton for rolling electric ingots was 25.8 per cent less than for the gas-heated ingots. This can best be accounted for by the assumption that the electric ingots were more evenly and thoroughly heated, which, is borne out by the temperature readings in Table 1, which shows that there was less drop in temperature of the electric ingots between the fourth and ninth pass.

Space Required for Electric Pits

As there are no regenerators or checker work required for electric pits, they require only about half the space of gas pits of the same capacity and when taking into consideration producer space, only about a third of the space is required, as compared with a complete producer-fired installation. Besides this saving in floor space, there is a large saving in foundation cost, and the absence of gas mains and stack enable electric pits to be more advantageously located with regard to the pit building and the mill. The savings in foundations, floor space stack and gas mains is such that the installation cost of an electric pit is less than the cost of a modern producer-fired installation and about the same as a well-designed modern gas pit fired with coke oven gas.

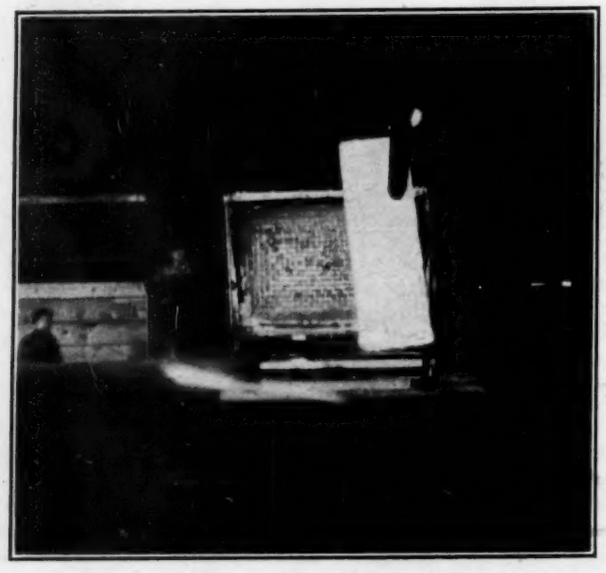

FIG. 6

Summary

The operation of this pit has demonstrated that the quality of heating is uniformly better, due to accurate control of temperature, uniformity of heating, elimniation of scale while in the pit, elimination of the cutting of the ingot, as in the case of sharp gas flames, and producing a better surface on the blooms.

The peak power demand on the mill is reduced, as is also the K. W. hours required for rolling.

There is a saving in space required over gas-fired pits, making it possible to install twice as many pits in a given space, as well as make a saving in foundations.

When taking into consideration the saving in scale and with the usual cost of steel mill power, the cost of heating is actually less than by any other means, provided the ingots can be charged into the pits at such temperatures as are now common in steel mill practice.

Further than this, it eliminates the discussions between the open hearth and blooming mill departments as to who caused the trouble in the steel.